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N.J. 08405

Operational Evaluation of Initial Data Link Air Traffic Control Services, Vol II Appendixes

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Nicholas J. Talotta, et al.

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Final Report

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Authors who have made a significant contribution to this report are:
Dr. Clark Shingledecker, NTI, and Mike Reynolds, Midwest Systems Research, Inc.

16. Abstract

This report details the results *are presented* of an operational evaluation of Initial Data Link Air Traffic Control (ATC) Services. The Operational Evaluation was conducted at the Federal Aviation Administration (FAA) Technical Center utilizing the Data Link test bed. Initial Data Link services were evaluated in order to identify service delivery methods which optimize controller acceptance, performance, and workload.

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PREFACE

This report documents a Federal Aviation Administration operational evaluation of the initial group of four air traffic control (ATC) services which have been designed for implementation on the Mode S Data Link system. The report is organized in two volumes.

Volume I contains the main body of the report. It includes a detailed description of the objectives of the evaluation and of the technical approach and test methods that were used. In addition, the primary results of the controller and aircrew portions of the study, conclusions, and recommendations are presented.

Volume II contains a set of appendixes to the report. These appendixes are referenced in Volume I and include technical documentation of the test hardware and of controller and pilot Data Link procedures. The appendixes also present detailed analyses of the data which were collected in the study. These appendixes were the basis for the primary results sections presented in Volume I.

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

INTRODUCTION.

The Federal Aviation Administration (FAA) is pursuing an initiative to develop and implement a Data Link system intended to enhance communications between ground-based air traffic control (ATC) and airborne systems. By providing digital information transfer with the ability to discretely address individual aircraft, Data Link is expected to relieve frequency congestion on existing voice radio channels while increasing the overall safety and productivity of the ATC system.

In order to insure that the introduction of Data Link will have an optimal positive impact on ATC, the FAA is conducting a program of research to guide system design efforts, evaluate the benefits of Data Link to ATC, and assess its effects on the air traffic controllers and aircrews who will use the system. Preliminary design studies completed during the past year (Talotta, et al., 1988, 1989) defined the detailed configurations for the initial group of ATC services and functions scheduled for implementation on Data Link. This report presents the results of the first operational evaluation of these initial capabilities in a full scale, ATC simulation manned by en route air traffic controllers. In addition, this report presents the findings of a concurrent study in which aircrews flying simulated aircraft in the ATC scenarios evaluated the initial services and a preliminary flight deck display/control device for Data Link communications.

OBJECTIVES.

The general purpose of the air traffic controller substudy was to assess the impact of the initial package of Data Link ATC services and functions in the context of a high fidelity simulation of en route ATC activity. The specific objectives were to measure the beneficial effect of Data Link on voice radio frequency congestion and to determine the impact on ATC performance and effectiveness, controller workload, and controller acceptance. The aircrew substudy was designed to evaluate the overall effectiveness of Data Link communications in aircraft operations both for the ATC services uplinked by the subjects in the controller substudy, and for a set of Data Link weather services available by direct aircrew interaction with simulated data bases.

DATA LINK SERVICES.

Two ATC services and two general Data Link functions were tested in the controller substudy. The ATC services were altitude assignment and transfer of communication. Data Link procedures for both of these services were designed to closely parallel current en route controller procedures with the addition of a minimal

number of keyboard actions. The status of Data Link transactions with aircraft were displayed in a Plan View Display (PVD) list and in the Full Data Block (FDB). Aircraft equipage and uplink eligibility were indicated by graphic characters in the first field of the FDB.

The Data Link ATC functions were menu text and free text. Menu text permits standard or frequently required ATC messages to be stored in a menu displayed on the PVD and selected for uplink as required. For the present study, menu messages were restricted to interim altitude assignments, sometimes combined with fix crossing restrictions. Free text provides controllers with the ability to engage in unconstrained ground-air communications using typed keyboard entries. This function is envisioned primarily as a back-up communications capability.

In addition to the primary ATC services delivered by the controllers, the aircrew substudy also examined a group of weather services which the pilots could request by direct downlink to a data base. These services were terminal forecast, winds/temperatures aloft, surface observation, and Pilot Reports (PIREPS). The aircrew received and responded to Data Link messages on a touch sensitive display.

APPROACH.

The evaluation was conducted in the FAA Technical Center's Data Link Test Bed. Two 30-minute test scenarios presented controllers with realistic en route ATC problems involving four sectors of adjacent airspace. A majority of the aircraft in the scenarios were simulated radar targets controlled by simulation operators. However, two of the targets in each test run were driven by high fidelity simulators representing a large transport aircraft and a small General Aviation (GA) aircraft. The airliner was manned by professional aircrews, while the small aircraft was flown by GA pilots.

The eight en route controllers participated in teams of four in 14 test runs in which Data Link equipage levels of the air traffic ranged from 0 (voice radio only) to 20 and 70 percent. In one of the runs, average uplink and downlink times were extended to assess the impact of "worst case" Data Link communication transmission delays. Each of the four participating aircrews and the four GA pilots participated in two Data Link runs and one baseline, voice-only run.

Controller measures included records of voice and Data Link usage, ratings of controller workload and service design acceptability, estimates of operational effectiveness, a wrap-up questionnaire, and extensive debriefing to elicit required Data Link design modifications. Aircrew measures evaluated perceptions of the effectiveness of the services and the usability of the preliminary

flight deck Data Link Input/Output (I/O) device. Times required for aircrew to detect and respond to Data Link and voice messages also were recorded.

PRIMARY RESULTS.

The controller substudy clearly demonstrated the benefit that the initial group of Data Link services can be expected to have on relieving frequency congestion of voice radio channels. The availablity of these functions reduced the number of controller voice transmissions by up to 41 percent, and total controller occupation time of the radio frequencies by up to 45 percent (see figure ES-1). Furthermore, as more Data Link equipped aircraft were introduced, there was an apparent increase in the efficiency of the communication process as requirements for repetition of voice messages and clarification of clearances were reduced.

The positive impact of Data Link was not achieved at any observed loss in ATC performance or controller capability. No critical ATC incidents were noted during the tests, and controller workload estimates were statistically identical in the voice and Data Link conditions (figure ES-1). The results also showed that Data Link transmission delays failed to have a negative effect on controller activities. All of the specific designs for the Data Link services were rated as operationally effective and acceptable to controllers.

The results of the aircrew substudy indicated that initial pilot perceptions of Data Link were positive and that its implementation would enhance the quality of air-ground communications. Additional findings indicated that the average total times between receipt of a message in the aircraft and the crew response to ATC ranged from 9.8 seconds in the voice conditions to 10.9 seconds in the Data Link conditions.

The workload associated with Data Link operations was considered acceptable to pilots. Furthermore, while the aircrew subjects indicated further development of display formats and crew coordination procedures will be required, they felt that persistent Data Link displays will reduce demands on pilot memory and that Data Link will be capable of replacing most functions currently served by voice radio in en route environments.

RECOMMENDATIONS.

Based on the results outlined above, it is recommended that the initial group of Data Link ATC services be incorporated as modifications to current en route ATC software and hardware, and that they be subjected to operational test and evaluation (OT&E). Minor outstanding design issues and potential enhancements revealed by the present study should be examined by the Air Traffic Data Link Validation Team (ATDLVT) and resolved. It is further

recommended that, because of the success of the operational evaluation and the positive impressions expressed by participating controllers and pilots, research and development work be expedited to extend Data Link applications to the full range of en route and terminal ATC services.

Because the development of refined flight deck interfaces has lagged behind corresponding ground controller work, it is recommended that additional studies be conducted to facilitate the integration of Data Link with the aircrew task environment.

Finally, in order to identify mutually acceptable rules and procedures which will govern pilot and controller communications using Data Link, it is recommended that a mechanism be created to promote relevant interactions between the ATDLVT and a representative pilot group.
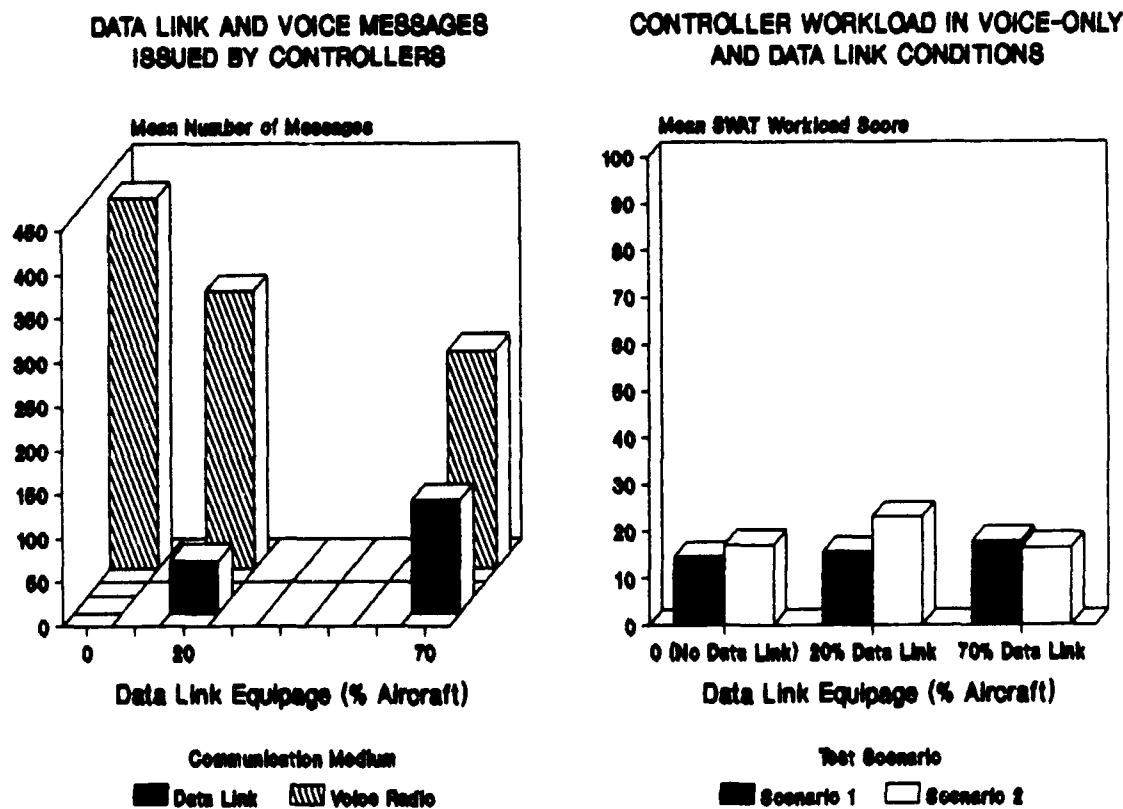

FIGURE ES-1. MESSAGES ISSUED AND WORKLOAD

APPENDIX A

ATC SCENARIO AND DATA LINK PROCEDURES

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LIST OF ILLUSTRATIONS

INTRODUCTION

A total of six operational evaluation scenarios were used in the evaluation of the Phase I Data Link services functions. Two of the scenarios were used to train the subject controllers and the other four were used to conduct the evaluation and collect data. The scenarios are the Operational Evaluation Training Scenarios (one with 70 percent Data Link-equipage and one with 100 percent Data Link-equipage), and the Operational Evaluation Scenarios (two with 20 percent Data Link-equipage and two with 70 percent Data Link-equipage). All of the scenarios were designed with the Universal Data Set (UDS) simulated airspace and run for 35 minutes. This appendix describes these scenarios, the relevant Menu Text messages used, and the En Route Controller Data Link chart that depicts the controller Data Link input message procedures.

DESCRIPTION OF THE OPERATIONAL EVALUATION TRAINING SCENARIO

The Operational Evaluation Training Scenario simulates a low volume en route air traffic environment. A description of the training scenarios with 70 and 100 percent Data Link-equipage are provided below.

OPERATIONAL EVALUATION TRAINING SCENARIO WITH 70 PERCENT DATA LINK-EQUIPAGE

This training scenario simulates a traffic flow that forms a circular routing between two airports. As shown in figure A-1, two low altitude sectors (03 and 17) and two high altitude sectors (07 and 10), are represented. Figure A-2 outlines the routes and the number of aircraft and Data Link-equipped aircraft in the scenario. The total number of aircraft (45) includes six aircraft (not shown in the figure A-2) that appear at the start of the run.

At the start of the scenario, six aircraft appear in flight in the high altitude sectors (three aircraft per sector). This provides an initial air traffic control (ATC) situation for the high altitude controllers. The departing aircraft appear simultaneously in sectors 03 and 17 at the two airports.

The aircraft starting in sector 03 appear at 12,000 feet on Rt. 1 (see figure A-2). This route contains nine aircraft (six are Data Link-equipped) departing the western airport (Philadelphia International) at fix point D3B. As the aircraft climb, they are given a clearance via a Menu Text message or radio to climb and maintain flight level 230. The westbound overflight route contains nine aircraft (five are Data Link-equipped). Of the nine aircraft, five are low altitude overflights that are designed to conflict with the departures in sector 03 (three aircraft are Data Link-equipped). After the clearance is received, the aircraft are handed off from sector 03 to high altitude sector 07.

A-1

SECTOR - 07   SECTOR - 10

HIGH

Base High Sector - 24,000 feet.

Base Low Sector - 23,000 feet.

LOW

D3B   G2E
PHILADELPHIA   ATLANTIC CITY
INTERNATIONAL   SECTOR - 03   SECTOR - 17   INTERNATIONAL
AIRPORT   AIRPORT
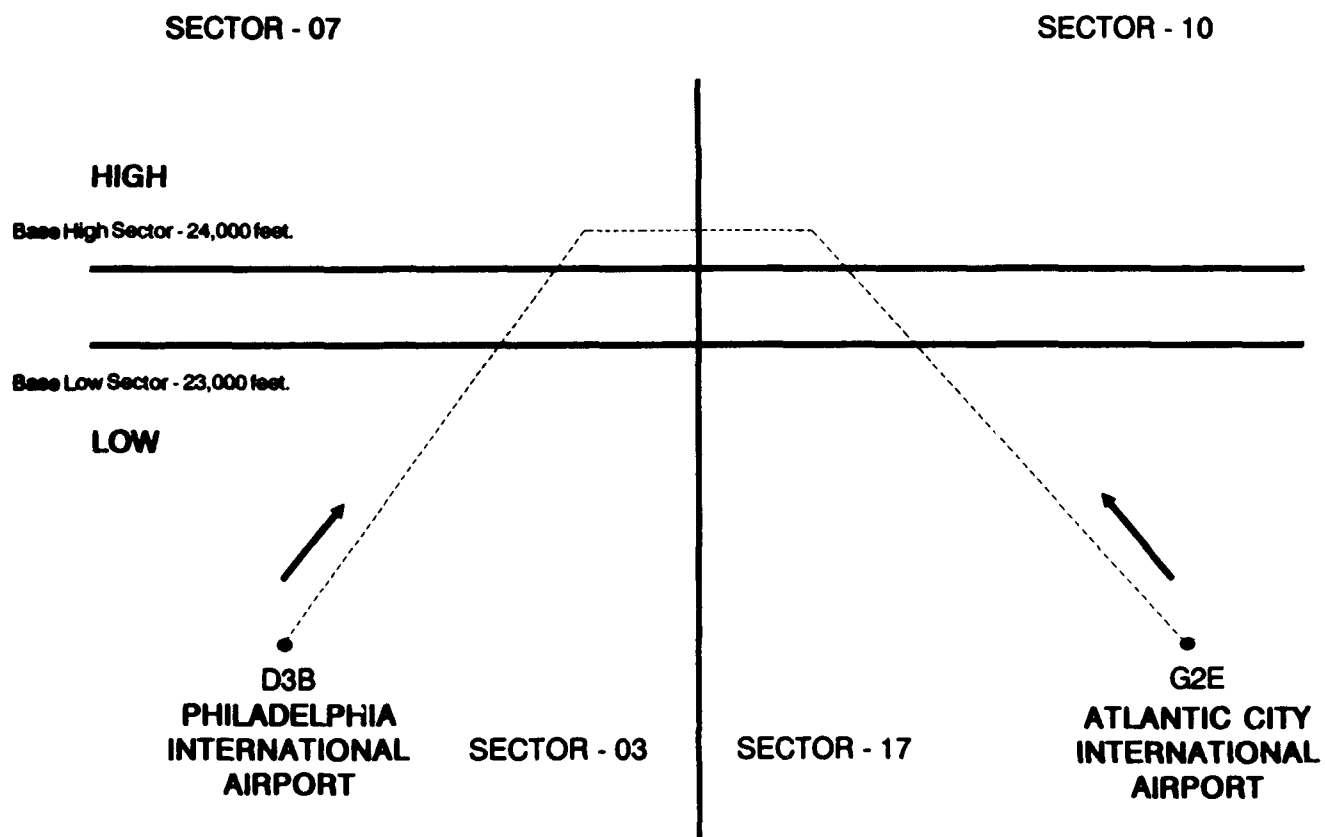
FIGURE A-1.   AIRSPACE SECTORIZATION DATA LINK OPERATIONAL
               EVALUATION TRAINING SCENARIO

FIGURE A-2. AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION TRAINING
SCENARIO (70% DATA LINK-EQUIPAGE)

In sector 07, the aircraft are given a clearance via a Menu Text message or radio to cross KMART and maintain flight level 250. The westbound overflight route also contains high altitude overflights that are designed to impact the traffic in sector 07. This overflight route contains four high altitude overflights (two are Data Link-equipped). The aircraft in sector 07 are handed off to high altitude sector 10. The aircraft are given a clearance via a Menu Text message or radio to cross BOIDS and maintain flight level 240. The aircraft in this sector are designed to be in conflict with the overflights starting at fix point F2E (see figure A-2). This overflight route contains 12 eastbound overflights (7 are Data Link-equipped). Of the 12 overflights, 4 are high altitude (3 are Data Link-equipped). The aircraft in sector 10 are handed off to low-altitude sector 17.

A clearance via a Menu Text message or radio to cross HOLTS and maintain 12,000 feet is given to the aircraft in sector 17. The low altitude overflights, of which four are Data Link-equipped, are designed to conflict with the aircraft in this sector. As the aircraft approach Atlantic City International Airport (G2E), they are terminated from the scenario.

The aircraft starting in sector 17 also appear at 12,000 feet on Rt. 2 (see figure A-2). This route contains nine aircraft (six are Data Link-equipped) departing the eastern airport (Atlantic City International) at fix point G2E. As each aircraft appears in the sector they are given a clearance via a Menu Text message or radio to climb and maintain flight level 230, and then are handed off to high-altitude sector 10. These aircraft are given a clearance via a Menu Text message or radio to cross RHOME and maintain flight level 260. The high altitude overflights, described in the above paragraph, are designed to conflict with the aircraft in this sector. The aircraft, after receiving the clearance, are handed off to high altitude sector 07.

When the aircraft enter sector 07, they are given a clearance via a Menu Text message or radio to cross GLADD and maintain flight level 240. The aircraft are impacted by the high altitude overflights on the eastbound overflight route that is described in the above paragraph. The aircraft in sector 07 are handed off to low altitude sector 03. A clearance via a Menu Text message or radio to cross BATON and maintain 12,000 feet is given to the aircraft in sector 03. The aircraft are terminated from the scenario at fix point D3B (Philadelphia International Airport).

The Menu Text messages for each of the four sectors in this scenario are shown in figure A-3. These messages appear on the sector position Plan View Displays (PVD's) at the beginning of the run. The controllers send the appropriate Menu Text message to the aircraft as the situation warrants. The messages with the leading plus sign, when sent to the aircraft, update the altitude field in the aircraft's full data block (FDB) on the PVD.

SECTOR-03
A.   120 X BATON MAIN
B. + 120 X BATON MAIN
C.   230 CLIMB MAIN
D. + 230 CLIMB MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-07
A.   240 X GLADD MAIN
B. + 240 X GLADD MAIN
C.   250 X KMART MAIN
D. + 250 X KMART MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-17
A.   120 X HOLTS MAIN
B. + 120 X HOLTS MAIN
C.   230 CLIMB MAIN
D. + 230 CLIMB MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-10
A.   240 X BOIDS MAIN
B. + 240 X BOIDS MAIN
C.   260 X RHOME MAIN
D. + 260 X RHOME MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

FIGURE A-3.   MENU TEXT DATA LINK OPERATIONAL EVALUATION TRAINING SCENARIO

OPERATIONAL EVALUATION TRAINING SCENARIO WITH 100 PERCENT DATA LINK-EOUIPAGE

This scenario (see figure A-4) is identical to the training scenario with 70 percent Data Link-equipage, except that no overflight routes are used and the total of 24 aircraft simulated are all Data Link-equipped.

DESCRIPTION OF THE OPERATIONAL EVALUATION SCENARIO #1

The Operational Evaluation Scenario #1 simulates a medium volume en route air traffic environment. Two scenarios (one with 70 percent Data Link-equipage and one with 20 percent Data Link-equipage) are described below.

OPERATIONAL EVALUATION SCENARIO #1 WITH 70 PERCENT DATA LINK-EOUIPAGE

This scenario simulates a traffic flow that forms a circular routing between two airports as shown in figure A-5. There are two low altitude sectors (03 and 17) and two high altitude sectors (07 and 10). The routes and the number of aircraft and Data Link-equipped aircraft are depicted in figure A-6. This scenario has a total of 63 aircraft. In addition, two aircraft simulators were used in this scenario: a Cessna 421 general aviation flight simulator (GAT II) located at the FAA Technical Center and a Boeing 727 flight simulator (NASA/AMES).

When the scenario begins, six aircraft appear in flight in the high altitude sectors (three aircraft per sector). This provides an initial ATC situation for the high altitude controllers. The departing aircraft begin simultaneously in both low altitude sectors (03 and 17) at each airport. When the aircraft appear in the low altitude sector 03, they are at 12,000 feet on Rt. 1 (see figure A-6) departing the western airport (Philadelphia International) at fix point D3B. This route contains nine aircraft (six are Data Link-equipped). The aircraft are given a clearance via a Menu Text message or radio to climb and maintain flight level 230. Within sector 03, there are two overflight routes, Rt. 3 and Rt. 4 (see figure A-6). These routes contain the same fix points but the traffic flows in opposite directions. Of the 12 aircraft, six aircraft (four are Data Link-equipped) are low altitude overflights that are designed to conflict with the departures in sector 03. Upon receipt of the clearance, the aircraft are handed off from sector 03 to high-altitude sector 07.

When the aircraft are accepted into sector 07, they are given a clearance via a Menu Text message or radio to cross KMART and maintain flight level 250. The bidirectional overflight route described above also contains six high altitude overflights (four are Data Link-equipped) that are designed to impact the traffic in sector 07. In addition, there is another high altitude overflight

ATLANTIC CITY
INTERNATIONAL
AIRPORT

G2E
9(9)
RL2

2GF
HOLTS

2FA
BONDS

G2F

F21

F2A

KMART
E2A

F2G

E2B

F3A
RHOME

E2C

E3A

D3A
BATON

E3B
GLADD

9(9)
RL1
DSB
PHILADELPHIA
INTERNATIONAL
AIRPORT

HIGH AND LOW
SECTOR BOUNDARY

HIGH SECTOR - 07 (FREQ 132.0)
LOW SECTOR - 03 (FREQ 133.0)

HIGH SECTOR - 10 (FREQ 123.0)
LOW SECTOR - 17 (FREQ 133.2)

FIGURE A-4.   AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION TRAINING
SCENARIO (100% DATA LINK-EQUIPAGE)

FIGURE A-5.   AIRSPACE SECTORIZATION DATA LINK OPERATIONAL
EVALUATION SCENARIO #1
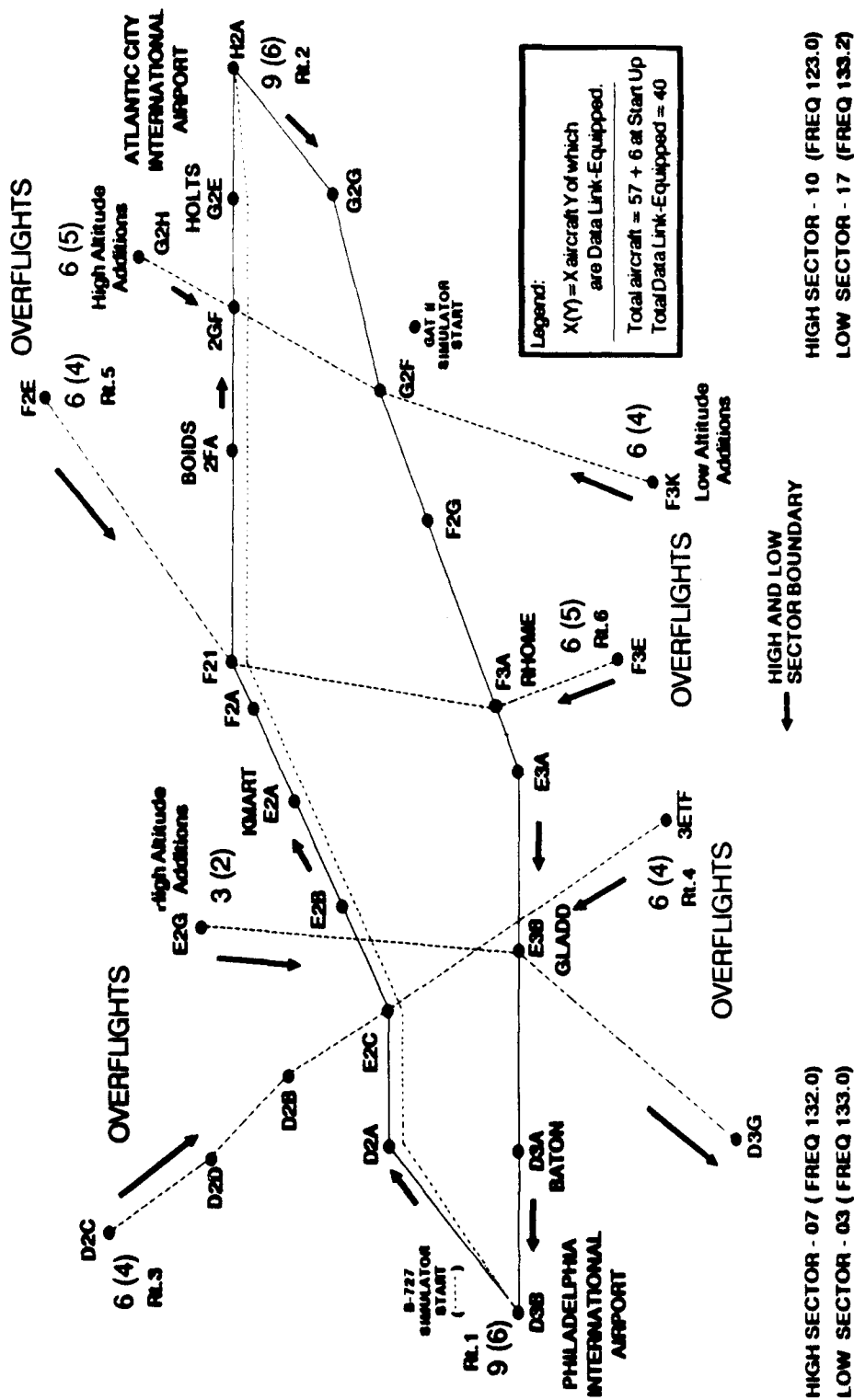
FIGURE A-6. AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION SCENARIO #1
(70% DATA LINK-EQUIPAGE)

route (High Altitude Additions) that contains three overflights (two are Data Link-equipped). High altitude sector 10 accepts aircraft transferred from sector 07.

The sector 10 controller gives a clearance via a Menu Text message or radio to cross BOIDS and maintain flight level 240 after the aircraft enter the sector. The two overflight routes, Rts. 5 and 6 (see figure A-6), create conflicting traffic in this sector. These routes contain the same fix points, but the traffic flows in two directions. These routes contain 12 high altitude overflights (9 are Data Link-equipped). Additional high altitude overflights are presented on the route labeled High Altitude Additions (see figure A-6) that contain six aircraft of which five are Data Link-equipped. The aircraft in sector 10 are handed off to low altitude sector 17.

After the aircraft enter sector 17, the controller gives a clearance via a Menu Text message or radio to cross HOLTS and maintain 12,000 feet. The aircraft in this sector are designed to conflict with low altitude overflights on the overflight route labeled Low Altitude Additions. There are six low altitude overflights (four are Data Link-equipped). The aircraft are terminated from the scenario at fix point H2A (Atlantic City International Airport).

The aircraft moving westbound appear in sector 17 at 12,000 feet, on Rt. 2 (see figure A-6) departing the eastern airport (Atlantic City International) at fix point H2A. This route contains nine aircraft (six are Data Link-equipped). The aircraft are given a clearance via Menu Text message or radio to climb and maintain flight level 230. The aircraft are impacted by low altitude overflights on the Low Altitude Additions route described in the above paragraph. After the clearance is given, the aircraft are handed off to high altitude sector 10. When the aircraft enter sector 10, they are given a clearance via a Menu Text message or radio to cross RHOME and maintain flight level 260. These aircraft are impacted by the high altitude overflight route described in the above paragraph. The controller in sector 10 hands off aircraft to high-altitude sector 07.

When the aircraft are accepted in sector 07, a clearance is given via a Menu Text message or radio to cross GLADD and maintain flight level 240. The high altitude overflights that are described in the above paragraph conflict with the aircraft in this sector. The aircraft in sector 07 are handed off to low altitude sector 03. A clearance via a Menu Text message or radio to cross BATON and maintain 12,000 feet is given to the aircraft in sector 03. The aircraft are terminated from the scenario as they approach Philadelphia International Airport.

The NASA/AMES simulator represents a departure traveling along Rt. 1 (see figure A-6) and appears to the controller no different

A-10

than the other aircraft in the scenario. Also, the GAT II simulator was assigned a special route as depicted in figure A-6. This aircraft starts at 8,000 feet in low altitude sector 17, climbs to 12,000 feet, and then is handed off to low altitude sector 03. The GAT II completes its route in sector 03 at an airport defined at fix oint 3ETF.

In figure A-7, the Menu Text messages are shown for each of the four sectors in this scenario. When the run begins, these messages are displayed on the sector PVD's. The appropriate message is sent, when the controller takes an action, to the aircraft as the situation warrants. The messages with the leading plus sign, when sent to the aircraft, update the altitude field in the aircraft's full data block on the PVD.

OPERATIONAL EVALUATION SCENARIO #1 WITH 20 PERCENT DATA LINK-EQUIPAGE

This scenario consists of a total of 63 aircraft of which 19 are Data Link-equipped, as shown in figure A-8. The number of Data Link-equipped aircraft is the only difference between the two versions of Operational Evaluation Scenario #1.

DESCRIPTION OF OPERATIONAL EVALUATION SCENARIO #2

The Operational Evaluation Scenario #2 simulates a realistic, high volume en route air traffic environment sample of arrival and departure sectors. The information below describes the scenarios with 70 and 20 percent Data Link-equipage.

OPERATIONAL EVALUATION SCENARIO #2 WITH 70 PERCENT DATA LINK-EQUIPAGE

This scenario represents two separate traffic flows that operate independently of each other. The two traffic flows represent arrival and departure routes in an en route center. In each of the two traffic flows there is one low altitude sector and one high altitude sector as shown in figure A-9. Of the 78 aircraft, 4 (not shown in figure A-10) appear on the arrival routes at the start of the run. In addition, two aircraft simulators were used in this scenario: a Cessna 421 GAT II located at the FAA Technical Center and a Boeing 727 flight simulator (NASA/AMES).

The first of the two traffic flows in the scenario simulate departures from an airport (upper portion of figure A-10) that fly through low altitude departure sector 03 and high altitude departure sector 10. The aircraft begin in sector 03 at 12,000 feet along one of the two departure routes, Rt. 1 or Rt. 2 (see figure A-10). Each departure route contains 12 aircraft (10 in each route are Data Link-equipped) departing the western airport (Philadelphia International) at fix point D3B. The aircraft are given a clearance via a Menu Text message or radio to climb and maintain flight level

SECTOR-03
A.　120 X BATON MAIN
B. + 120 X BATON MAIN
C.　230 CLIMB MAIN
D. + 230 CLIMB MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-17
A.　120 X HOLTS MAIN
B. + 120 X HOLTS MAIN
C.　230 CLIMB MAIN
D. + 230 CLIMB MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-07
A.　240 X GLADD MAIN
B. + 240 X GLADD MAIN
C.　250 X KMART MAIN
D. + 250 X KMART MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-10
A.　240 X BOIDS MAIN
B. + 240 X BOIDS MAIN
C.　260 X RHOME MAIN
D. + 260 X RHOME MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

FIGURE A-7.　MENU TEXT DATA LINK OPERATIONAL EVALUATION SCENARIO #1
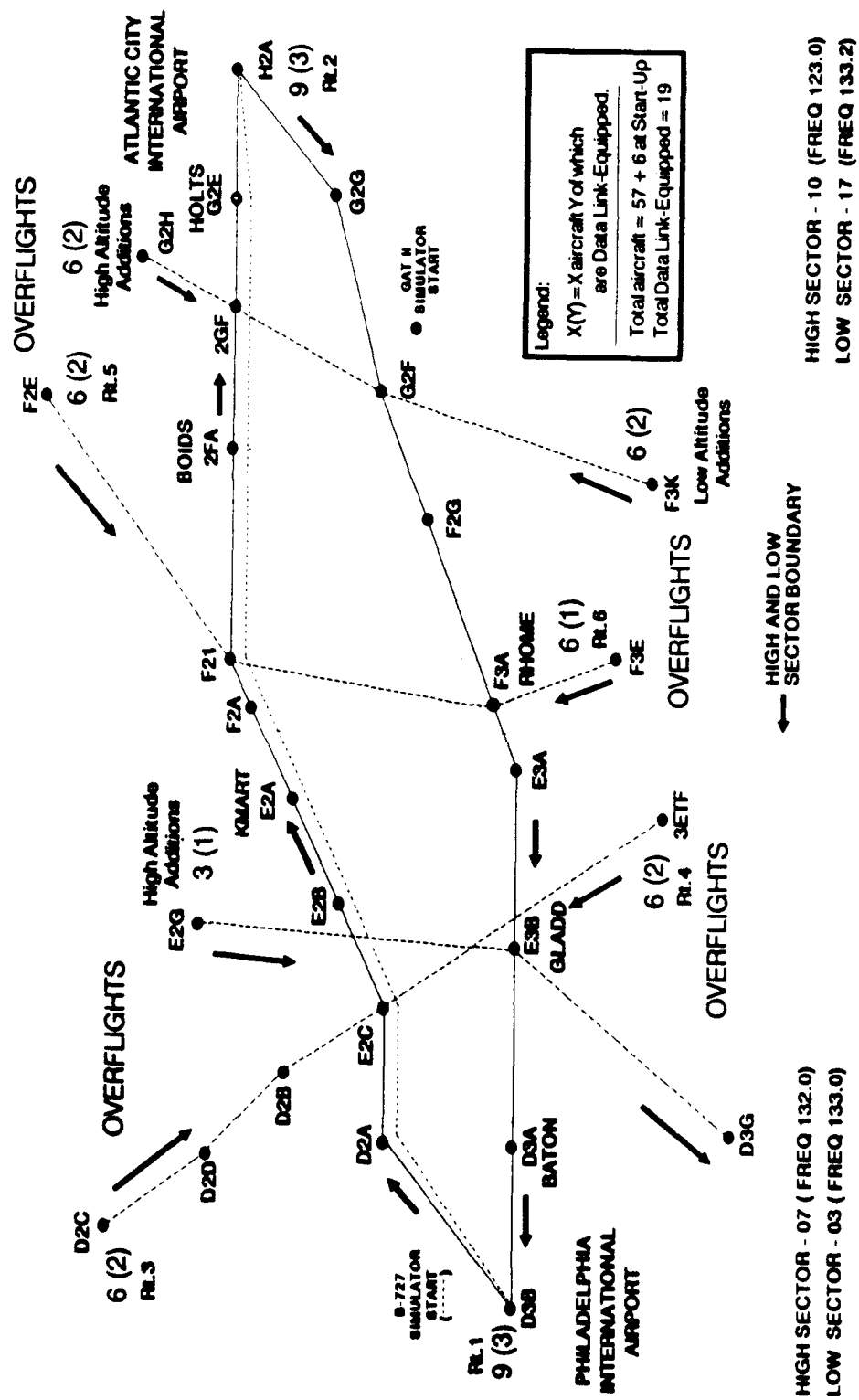
FIGURE A-8.   AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION SCENARIO #1
(20% DATA LINK-EQUIPAGE)

SECTOR - 07 | SECTOR - 10

HIGH

Base High Sector - 24,000 ft.

Top Low Sector - 23,000 ft.

LOW

D3B
PHILADELPHIA
INTERNATIONAL
AIRPORT

SECTOR - 03 | SECTOR - 17

G4F
ATLANTIC CITY
INTERNATIONAL
AIRPORT
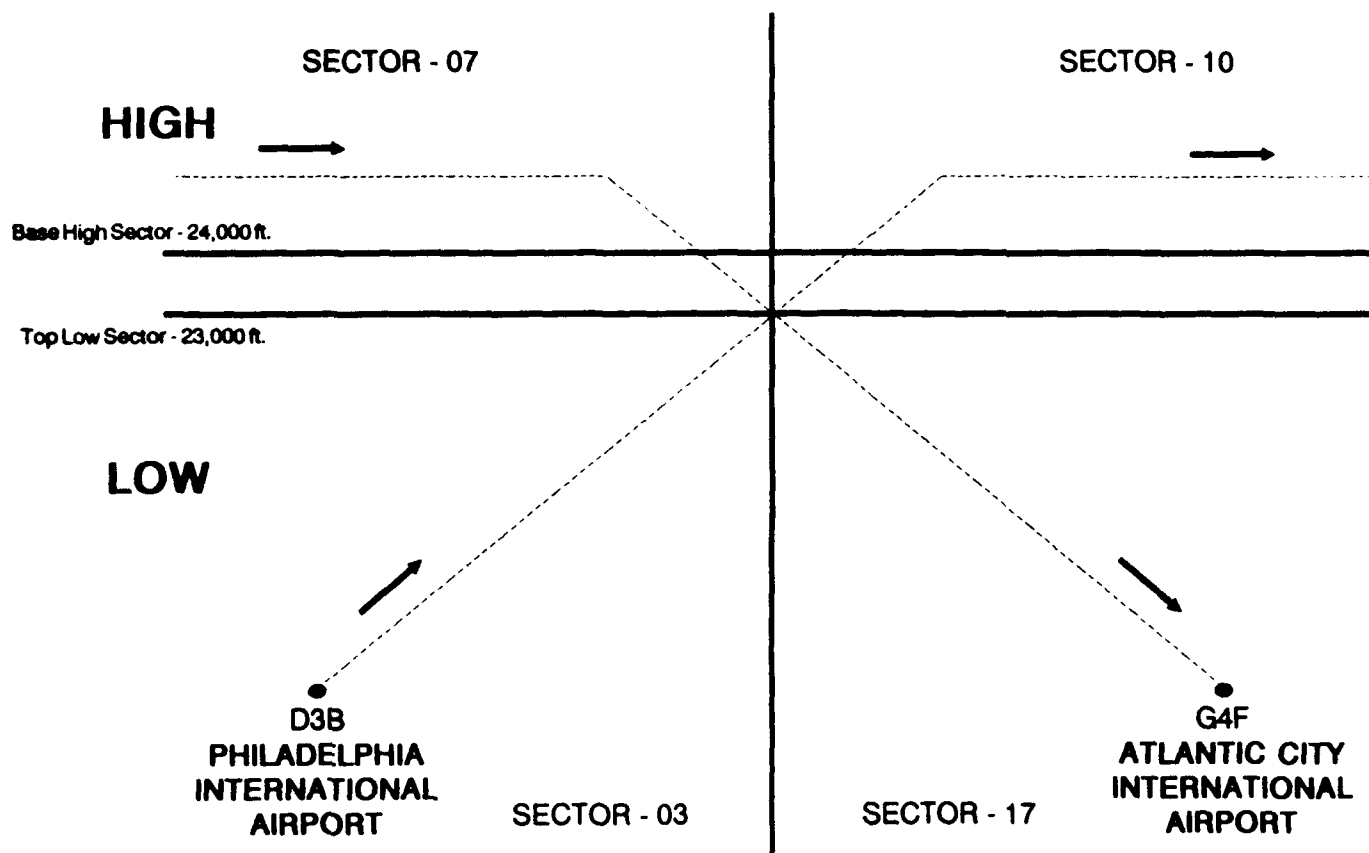
FIGURE A-9.   AIRSPACE SECTORIZATION DATA LINK OPERATIONAL
EVALUATION SCENARIO #2
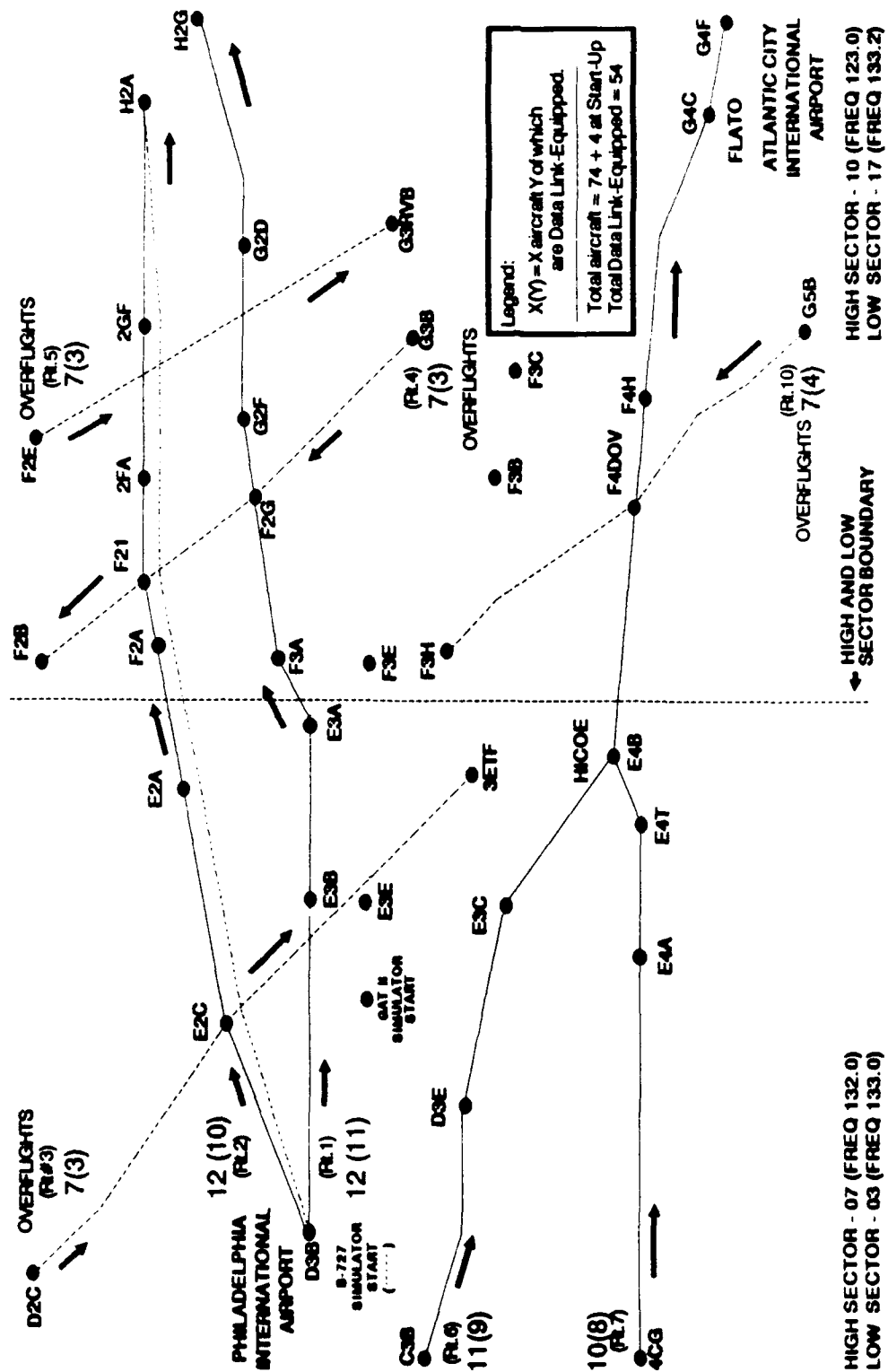
FIGURE A-10. AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION SCENARIO #2 (70% DATA LINK-EQUIPAGE)

230. Within sector 03, there is one overflight route, Rt. 3 (see figure A-10), containing seven aircraft (three are Data Link-equipped) that are designed to conflict with the departures. The sector 03 controller hands off aircraft to high altitude sector 10. The aircraft in this sector conflict with aircraft on the two high altitude overflight routes. Each of the overflight routes in sector 10 contains seven aircraft (three in each route are Data Link-equipped). This portion of the scenario contains 45 aircraft (29 are Data Link-equipped).

The second of the two traffic flows simulates aircraft arriving at an airport (lower portion of figure A-10) that fly through high altitude arrival sector 07 and low altitude arrival sector 17. At the start of this scenario, four aircraft are already en route. This provides an initial ATC situation in this portion of the scenario. The remaining aircraft begin in high altitude arrival sector 07 along one of the two routes, Rt. 6 and Rt. 7 (see figure A-10). Rt. 6 contains 13 aircraft (11 are Data Link-equipped) and Rt. 7 contains 9 aircraft (8 are Data Link-equipped). The aircraft along Rts. 6 and 7 are given a clearance via a Menu Text message or radio to descend and maintain to flight level 240 and/or cross HICOE and maintain flight level 240. As the aircraft are separated, they are merged into one stream of traffic before they are handed off to low altitude arrival sector 17. When sector 17 receives control of the aircraft, a clearance via a Menu Text message or radio is given to descend and maintain an altitude of 12,000 feet and/or cross FLATO and maintain an altitude of 12,000 feet. One low altitude overflight route, Rt. 10, that contains seven aircraft (four are Data Link-equipped) interfere with the stream of arrivals. All of the arrivals are terminated at the eastern airport (Atlantic City International) at fix point G4F. This portion of the scenario contains 29 aircraft (23 are Data Link-equipped).

The NASA/AMES simulator was a departure traveling along Rt. 2 (see figure A-10) and appears to the controller as one of the Boeing 727 aircraft. This aircraft participated in the scenario in the same manner as the other aircraft on this route. The GAT II simulator was assigned a special route to travel that is depicted in figure A-10. This aircraft starts at 9,000 feet in low altitude departure sector 03, climbs to 10,000 feet, and then handed off to low altitude arrival sector 17. The GAT II completes its route in sector 17 at an airport defined at fix point F3G.

The Menu Text messages, depicted in figure A-11, defined for each of the four sectors in this scenario, appear on the sector PVD's at the beginning of the run. As the situation warrants, the appropriate Menu Text message is sent, upon a computer input action, to the aircraft. The messages with the leading plus sign when sent to the aircraft update the altitude field in the aircraft's FDB on the PVD.

SECTOR-03
A.   230 CLIMB MAIN
B. + 230 CLIMB MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-07
A.   240 DESCEND MAIN
B. + 240 DESCEND MAIN
C.   240 X HICOE MAIN
D. + 240 X HICOE MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-17
A.   120 X FLATO MAIN
B. + 120 X FLATO MAIN
C.   120 DESCEND MAIN
D. + 120 DESCEND MAIN
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

SECTOR-10
R. REQUESTED ALTITUDE
Z. DEFINED ALTITUDE

FIGURE A-11.   MENU TEXT DATA LINK OPERATIONAL EVALUATION SCENARIO #2

This scenario consists of 78 aicraft of which 18 are Data Link-equipped as shown in figure A-12. The number of Data Link-equipped aircraft is the only difference between the two versions of Operational Evaluation Scenario #2.

EN ROUTE RADAR CONTROLLER DATA LINK CHART

These charts (see figure A-13) are quick reference guides on the Data Link services/functions message input format. The Data Link services/functions listed on the charts are those included in the test bed. The first two charts provide procedures for entering Data Link messages; the last two charts provide additional information on the Data Link symbology and Data Link status list.

FIGURE A-12. AIRCRAFT ROUTING DATA LINK OPERATIONAL EVALUATION SCENARIO #2
(20% DATA LINK-EQUIPAGE)

PURPOSE	Q/A Key	CAT Key	FUNC Key	FIELD CONTENT	COMMENTS
DATALINK **Sector Set-Up Option** Service Active Mode		DLC	DATALINK SETTING	1 or ON 0 or OFF	ON will appear on PVD. OFF deletes the DATALINK set-up indicators from PVD
Status List Display		DLC	DATALINK SETTING	P or N	P = PVD / N = No Display Device
SERVICE **Altitude Assignment** Assigned Altitude	ASGD ALT (QZ)			ddd S AID	NAS & FDB updated on WILCO.
Interim Altitude	INTERIM ALT (QQ)			ddd S AID	FDB updated on WILCO.
MENU TEXT Interim Altitude	INTERIM ALT (QQ)			a AID	+ in Menu Text message updates the FDB. a is the reference letter of the Menu Text message.
Z-Menu Text	INTERIM ALT (QQ)			z ddd AID	FDB is not updated.
Free Text Uplink		DLC		T LLL AID or T LLL ALL	LLL(up to 20 characters). ALL option sends message to all aircraft under sector control.

FIGURE A-13.   EN ROUTE RADAR CONTROLLER DATA LINK CHART (SHEET 1 OF 4)

PURPOSE	Q/A Key	CAT Key	FUNC Key	FIELD CONTENT	COMMENTS
Transfer of Communications Accept Handoff	(QZ/QN)			AID	Accept Handoff causes message to be placed in HELD status. The initial controller can send, resend or delete msg.
Resend Transfer of Communications		DLC		TB SL MSG ------ AID	Trackball Status List. ------ Resends the first failed TOC message.
		DLC		TB AC Track	Trackball AC track symbol.
List Management Menu Text List Reposition List	PVD			T TB	Trackball to new PVD area.
Delete Menu Text Message		DLC	MENUBUILD	a	a is the reference letter of the Menu Text message.
Status List Reposition List	PVD			L TB	Trackball to new PVD area.
Delete Status List Message				D TB MSG	Trackball Status List Message.

FIGURE A-13. EN ROUTE RADAR CONTROLLER DATA LINK CHART (SHEET 2 OF 4)

Field Name	Format	Comments
AID (02)	La (a)(a)(a)(a) dda, dddd; trackball	
Assigned Alt (08)	ddd	
List Display Ident (61)	L, T	Status, Menu Text
Interim Altitude	ddd or Rddd or T	
Trackball (65)	TB	
Text	T	Up to 20 characters.
FLID	L a(a)(a)(a)(a)	

Field Name	Format	Comments
Service Type Ident	AA, TC, MT, FT	Altitude Assignment, Transfer of Comm, Menu Text Uplink, Free Text Uplink,
Data Link (DL) Equipped without DL Eligibility	◇	Symbol appears in data block next to FLID.
DL Equipped with DL Eligibility	⊠	Symbol appears in data block next to FLID.
DL Equipped DL Eligibility Pending DL Message	↖	Waiting for response to uplinked TOC message.
Altitude Assignments and Interim Altitude Data Link Status	S,W,F	Symbol appears in FDB Field B, S = Sent, W = Wilco, F = Failed

FIGURE A-13.   EN ROUTE RADAR CONTROLLER DATA LINK CHART (SHEET 3 OF 4)

A-22

DATA LINK STATUS LIST FORMAT

Examples:

UAL1234 TC 23.450 WIL

TB POINT   FLID   Service Type   Data Area   Status Indicator

TWA2579 AA   270   DLV
DAL1680 MT   A 250   SNT
BAL8048 FT   CALL C   NAK

Where:
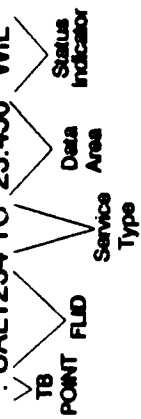
TB Point = Designated area to Trackball.

FLID = Aircraft Identification or Call Sign (up to 7 characters).

Data Area = An area that shows the instruction/command sent to pilot (up to 6 characters).

Status Indicator = Current status of message (SNT=SENT, DLV=DELIVERED, WIL=WILCO, HLD=HELD, NAK=No Acknowlegment, FAI=FAILED).

FIGURE A-13. EN ROUTE RADAR CONTROLLER DATA LINK CHART (SHEET 4 OF 4)

APPENDIX B

MEASURES OF CONTROLLER WORKLOAD, DESIGN PREFERENCE,
AND OPERATIONAL EFFECTIVENESS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

INTRODUCTION

This appendix presents the detailed results of the operational evaluation study that were obtained from controllers during the simulation runs in the Data Link test bed. These results were derived from overall workload ratings taken after each test condition, and from ratings of operational effectiveness/suitability and controller acceptance/preference collected immediately after each subject had completed the full series of seven test runs. In addition, written comments elicited from the controllers during the test bed sessions are summarized here.

WORKLOAD MEASUREMENT

SUBJECTIVE WORKLOAD ASSESSMENT TECHNIQUE (SWAT) SCALE DEVELOPMENT.

Controller workload was assessed by the test subjects immediately following each simulation run using a subjective rating method known as the SWAT. SWAT was developed in the early 1980's by U.S. Air Force researchers in order to provide a standard rating method that results in quantitative, interval level estimates of the workload experienced by operators during simulation and operational tests (Reid and Nygren, 1988). SWAT was used successfully for evaluation of air traffic controller workload in both of the preliminary Data Link Mini Studies (Talotta, et al., 1988, 1989).

SWAT consists of a rating scale which requires the subject to judge the workload experienced during a period of task performance as a combination of ratings on three, 3-point scales representing the dime.isions of time load, mental effort load, and psychological stress. The SWAT scale is shown in figure B-1.

In order to generate quantitative data using this scale, subjects provide information on how time, effort, and stress combine to produce their individual concepts of mental workload. This scale development exercise is accomplished prior to actual data collection by asking subjects to sort a set of 27 cards on which are printed all possible combinations of the descriptors on the time, effort, and stress scales. Subjects sort the cards to produce an ordering that represents situations ranging from low to high workload. The sorts are then subjected to computerized conjoint analysis which determines the combinatory rule governing each subject's sequence. An iterative routine is then applied to generate an interval scale value for each of the possible time, effort and stress ratings which preserves the original ordering and fits the identified rule. The result of this process is a look-up table for each subject, or group of similar subjects, that converts the discrete time, effort, and stress ratings to an overall unitary scale with values ranging from 0 to 100.

TIME LOAD

1. Often have spare time. Interuptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interuptions or overlap among activities occur frequently.
3. Almost never have spare time. Interuptions or overlap among activities are very frequent or occur all the time.

MENTAL EFFORT LOAD

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention is required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD

1. Little confusion, risk, frustration or anxiety and can easily be accomodated.
2. Moderate stress due to confusion, frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration or anxiety. High to extreme determination and self-control required.

FIGURE B-1.   SWAT RATING SCALE

Prior to participation in the test bed sessions, all eight subjects completed the SWAT card sort task described above. The instructions provided to subjects for the card sort and for use of the SWAT scale are included as the final section of this appendix.

A Kendall's Coefficient of Concordance computed on the card sorts produced by the eight subjects yielded an index of association among the card orderings of 0.79. In the SWAT methodology, this level of agreement is considered acceptable for computation of a group scale. To evaluate the "goodness of fit" of the average group sort data to an additive model, the required axiom tests of conjoint measurement were applied. These tests resulted in 0 violations out of 324 tests for the independence axiom, 0 violations out of 8 tests for the double cancellation axiom, and 7 violations out of 324 tests for the joint independence axiom. Since this finding is well below the SWAT criterion of 20 total violations for rejection of the model, a group scale was computed for interpretation of each of the 27 possible SWAT time, effort, and stress ratings. This numerical scale assigned an approximate importance of 37.37 percent to the time factor, 21.67 percent to the effort factor, and 40.96 percent to the stress factor. All subsequent analyses of SWAT ratings obtained from the subjects in the test bed runs were performed on the corresponding values obtained from this unitary scale. Table B-1 presents the card order data for each subject as well as the derived scale values assigned to each possible rating.

SWAT WORKLOAD RESULTS.

All subjects completed a SWAT rating immediately following each of the seven test runs. The primary statistical analysis performed on the SWAT scores was based on the data from the basic test runs in which the subjects controlled traffic in a baseline (no Data Link) condition, and under 20 percent and 70 percent mixes of aircraft Data Link equipage. These conditions were repeated for two different ATC scenarios, yielding six test runs for each subject. Subjects were tested in two groups of four subjects each. The two groups experienced the baseline and Data Link conditions in different sequences in order to reduce rating bias and to permit inspection of the effects of scenario familiarization.

A three-factor ANOVA (Group x Scenario x Equipage) with repeated measures on the final two factors was performed on the data from the basic test runs. This analysis tested the significance of each of these main effects as well as any interactions among the factors. Figure B-2 shows the mean SWAT scores produced by the combined groups as a function of Data Link equipage level and test scenario.

The results of the analysis revealed no significant effect of any of the three primary factors ($F<1$). That is, SWAT ratings did not differ significantly between groups, scenarios, or among the

TABLE B-1. SWAT CARD SORTS AND GROUP SCALE CONTROLLER SURVEY

TES	1	2	3	4	5	6	7	8	Group Scale Value
111	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.0
112	10.00	7.00	6.00	4.00	3.00	4.00	2.00	11.00	22.1
113	13.00	12.00	15.00	8.00	9.00	7.00	3.00	21.00	41.0
121	2.00	2.00	3.00	5.00	2.00	2.00	4.00	4.00	10.8
122	11.00	5.00	13.00	6.00	4.00	8.00	6.00	13.00	32.9
123	14.00	16.00	21.00	9.00	11.00	10.00	7.00	23.00	51.8
131	3.00	8.00	7.00	7.00	5.00	5.00	5.00	8.00	21.7
132	12.00	13.00	17.00	16.00	10.00	15.00	8.00	16.00	43.7
133	15.00	20.00	25.00	18.00	14.00	22.00	9.00	24.00	62.6
211	4.00	3.00	2.00	2.00	6.00	3.00	10.00	2.00	14.9
212	16.00	6.00	11.00	10.00	15.00	9.00	11.00	10.00	37.0
213	19.00	17.00	16.00	11.00	13.00	12.00	14.00	20.00	55.9
221	5.00	4.00	4.00	12.00	7.00	6.00	12.00	5.00	25.7
222	17.00	15.00	14.00	14.00	12.00	13.00	15.00	14.00	47.8
223	20.00	23.00	23.00	15.00	18.00	21.00	16.00	18.00	66.7
231	6.00	10.00	9.00	19.00	16.00	14.00	13.00	6.00	36.6
232	18.00	19.00	20.00	20.00	8.00	18.00	17.00	15.00	58.6
233	21.00	25.00	26.00	24.00	17.00	25.00	18.00	26.00	77.5
311	7.00	9.00	5.00	3.00	19.00	11.00	19.00	3.00	37.4
312	22.00	18.00	12.00	22.00	20.00	16.00	20.00	12.00	59.5
313	25.00	24.00	19.00	21.00	21.00	23.00	21.00	22.00	78.3
321	8.00	11.00	8.00	13.00	22.00	17.00	22.00	7.00	48.2
322	23.00	21.00	18.00	23.00	23.00	19.00	23.00	19.00	70.3
323	26.00	26.00	24.00	25.00	24.00	24.00	24.00	25.00	89.2
331	9.00	14.00	10.00	17.00	25.00	20.00	25.00	9.00	59.0
332	24.00	22.00	22.00	26.00	26.00	26.00	26.00	17.00	81.1
333	27.00	27.00	27.00	27.00	27.00	27.00	27.00	27.00	100.0

Note: TES = Time Load, Mental Effort, and Psychological Stress Load

MEAN SWAT WORKLOAD SCORE
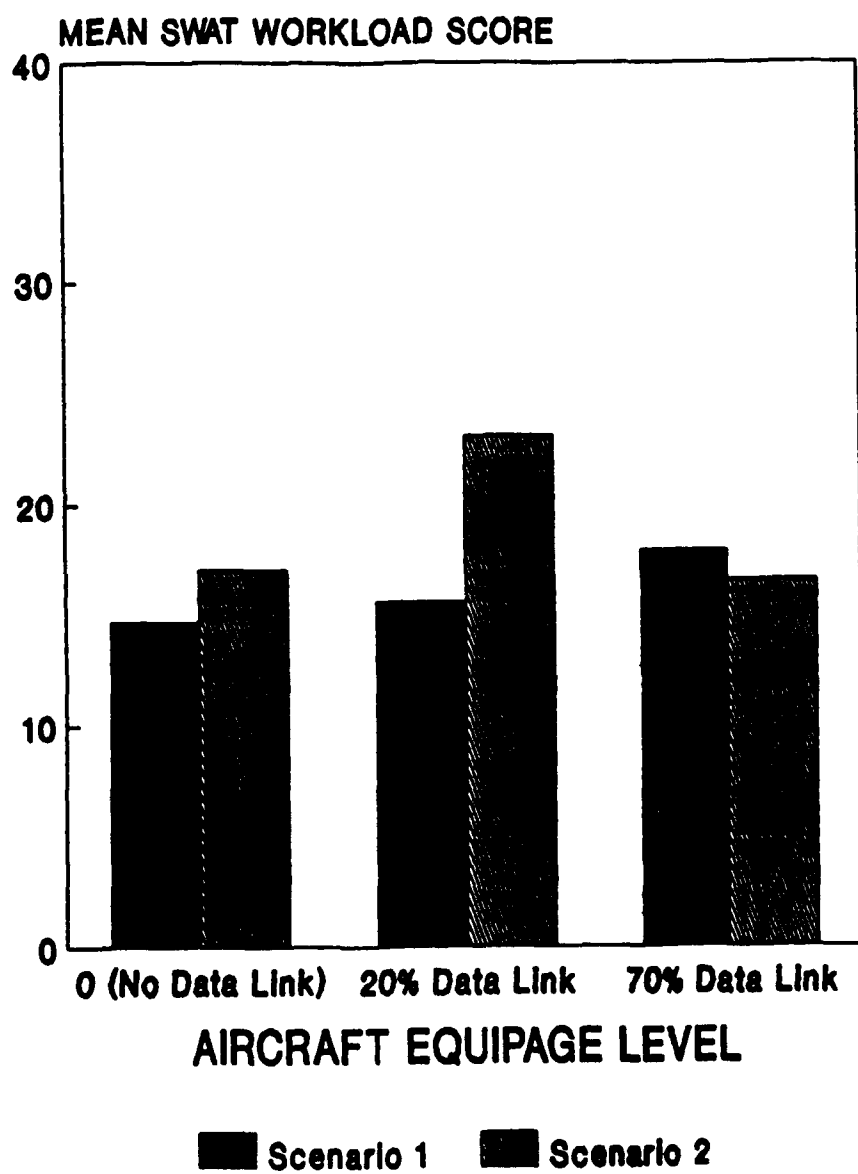
FIGURE B-2.   CONTROLLER WORKLOAD IN VOICE ONLY AND DATA LINK
              CONDITIONS

baseline and Data Link test conditions. In addition, no two-way interactions among the factors were significant. However, the three-way interaction among groups, scenarios, and equipage levels was significant $(F(2,12)=3.89, p<.05)$.

This complex interaction effect can be interpreted by inspecting the effect of testing sequence within the two test scenarios. In designing the operational evaluation study, it was decided that the subjects would not receive explicit practice with, or exposure to, the test scenarios in order to maintain motivation during the repeated testing. This decision introduced the possibility that workload ratings could be affected by familiarization with the scenarios during testing, and that these effects would confound the impact of equipage levels and their comparison to the baseline condition. As noted earlier, an attempt was made to provide a partial control for this confounding by testing the two groups with different orders of exposure to the Data Link and non-Data Link conditions.

To address the testing sequence effect, the ANOVA was repeated with test order substituted for the equipage factor. The SWAT scores are plotted to show this effect in figure B-3. The apparent decrease in perceived workload over test trials that can be seen in figure B-3 was confirmed by the analysis. The test order factor was significant $(F(2,12)=5.53, p<.05)$. No other main effects or interactions were statistically significant.

Figure B-4 clearly shows the apparent dominance of the scenario familiarization effect on workload ratings. Since the 70 percent Data Link condition was presented in the second position of the test sequence for both groups in both scenarios, this figure focuses on the baseline 0 and 20 per.ent equipage levels which alternated as the first and last conditions within each scenario. As figure B-4 indicates, the primary determinant of which of the two conditions received the greater workload rating was the order of presentation: if Data Link was used first in a scenario, it was rated as the more difficult test; if baseline was tested first, its workload was greater than Data Link.

This result suggests that the original three-way interaction obtained in the primary analysis was largely attributable to the sequence effect which was reflected in the combination of the group, scenario and equipage factors. More importantly, this finding confirms and extends the results of the first analysis, and indicates that:

1. Controller workload was unaffected by the substitution of Data Link procedures for current voice radio procedures (for the ATC service designs tested).

2. Controller workload did not differ in the low (20 percent) and high (70 percent) Data Link-equipage environments.

MEAN SWAT WORKLOAD SCORE

ORDER OF TESTS

SCENARIO

■ Scenario 1   ▨ Scenario 2

FIGURE B-3.   TEST SEQUENCE EFFECT ON CONTROLLER WORKLOAD

MEAN SWAT WORKLOAD SCORE

AIRCRAFT EQUIPAGE LEVEL

Test Sequence

Grp 1 0% → 20%   Grp 2: 20% → 0%

SCENARIO 1

MEAN SWAT WORKLOAD SCORE

AIRCRAFT EQUIPAGE LEVEL

Test Sequence

Grp 1 20% → 0%   Grp 2: 0% → 20%
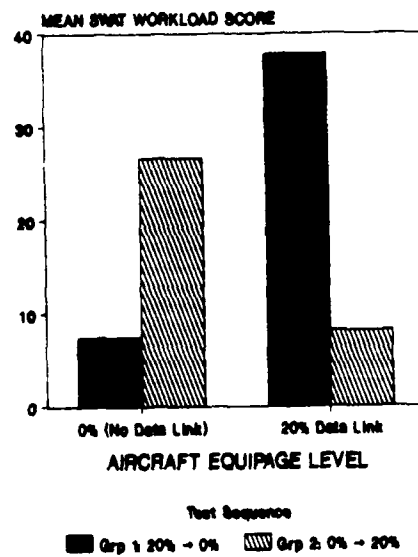
SCENARIO 2

FIGURE B-4.   CONTROLLER WORKLOAD 0% AND 20% TESTS

3. Occasional observed differences in workload between voice and Data Link tests were not statistically significant and were attributable to scenario familiarity, regardless of the procedures used.

A final statistical test performed on the SWAT workload data compared the 70 percent Data Link equipage test run under scenario 1 with a seventh test condition. This condition was identical to the former test, but doubled average Data Link time delays to a predicted "worse case" level. The mean SWAT score for the combined groups in the normal delay condition was 17.86, while in the extended delay run the mean score was 16.06. No statistically significant difference between the means was detected $(t(7)=.278, p>.3)$.

RATINGS OF OPERATIONAL EFFECTIVENESS

After completing all seven test runs, each subject rated the tested Data Link service designs in terms of how well they would meet operational requirements under the full range of ATC environments and variations. The subjects were instructed to rate the effectiveness of each design independently of whether they felt it was easy to use or would be acceptable to controllers. The rating scale permitted the subjects to classify a service as "not operationally suitable" or on a scale ranging from 1 (highly effective) to 7 (minimally effective).

None of the services were rated "not operationally suitable" by any of the subjects. The median ratings for each service are shown in figure B-5. Wilcoxon nonparametric statistical tests indicated that Transfer of Communication (TOC), Altitude Assignment (AA) and Menu Text for Interim Altitudes (MT) were all rated higher than the scale midpoint (meets most operational requirements). Additional tests showed that TOC and MT were equally effective designs and that both of these were more effective than AA. AA was significantly more effective than Free Text (FT). Though rated lowest of the group, FT was not rated significantly lower than the scale midpoint.

RATINGS OF CONTROLLER ACCEPTANCE/PREFERENCE

The subjects were also asked to classify each of the tested service designs according to how acceptable the procedures, displays and inputs would be to controllers. Subjects were instructed to make this rating independently from their evaluation of the perceived effectiveness of the design. The rating scale permitted the subjects to classify a service as "completely unacceptable" or on a preference scale ranging from 1 (highly preferred) to 7 (acceptable, but not preferred).

None of the tested services were rated as "completely unacceptable" by any of the subjects. The median preference ratings are shown
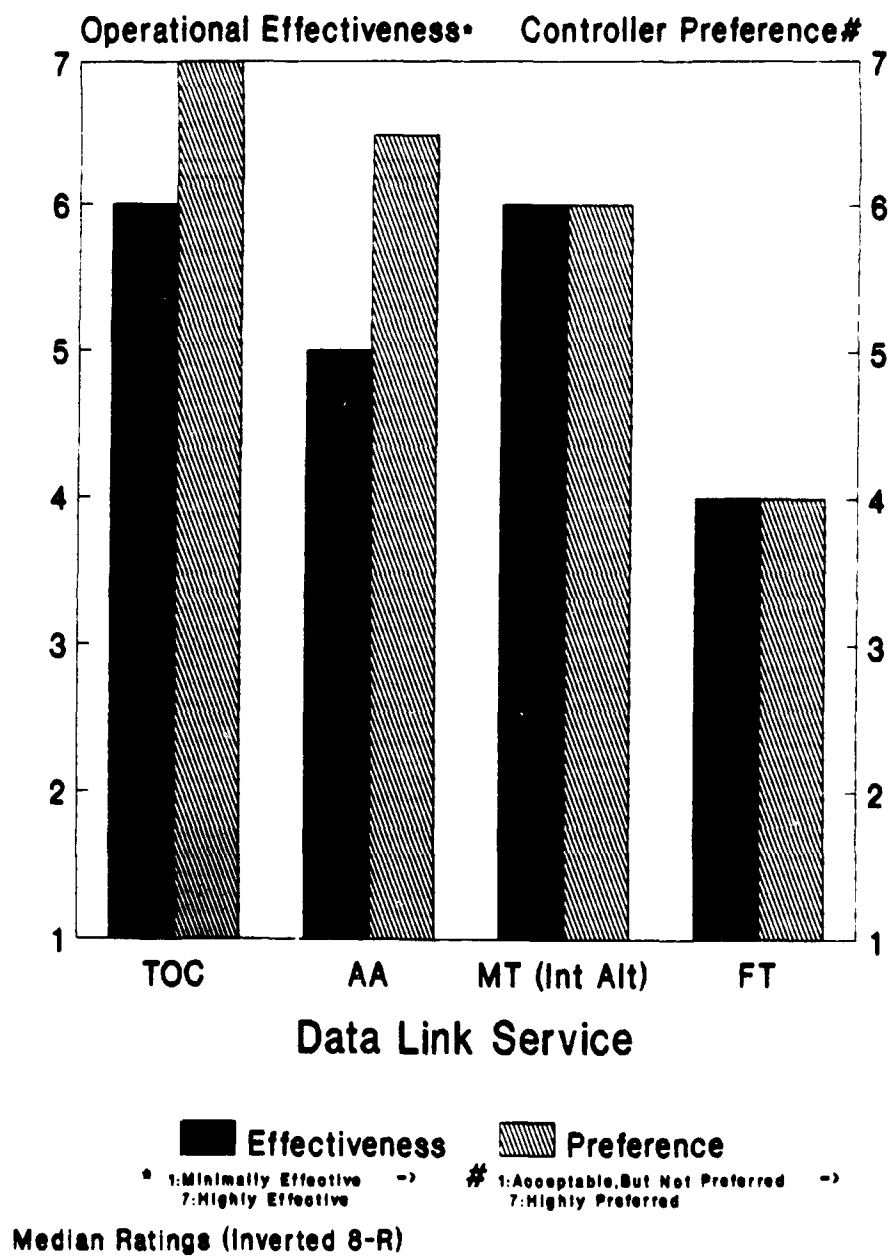
FIGURE B-5.   OPERATIONAL EFFECTIVENESS AND CONTROLLER PREFERENCE

in figure B-5. Wilcoxon tests indicated that TOC, AA, and MT were all rated higher than the scale midpoint (moderately preferred). Furthermore, TOC was significantly more preferred than AA, which was, in turn, more highly preferred than MT. Though rated significantly less preferred than the other three services, FT was not rated significantly lower than the scale midpoint.

Controller comments were solicited on the SWAT rating forms and on "incident forms," which were completed following each simulation test run. Additional comments were recorded by controllers while completing the ratings of effectiveness and preference for each service. Because similar comments were obtained on the inter-trial and post-test data sheets, they were analyzed as a single group. The following are brief, categorical summaries of these comments:

TESTING SEQUENCE.

As noted in the presentation of the SWAT data, the order of testing within a scenario appeared to profoundly affect the subjects' perceived workload, regardless of whether a test involved voice radio procedures or Data Link. Subject comments strongly support the conclusion that any cases of increased workload under Data Link or Baseline conditions were attributable to unfamiliarity with the test scenario. A total of nine comments which referred to the relationship between the test scenario and workload were recorded. Three of the remarks indicated that the workload of the scenario was high. All of these were recorded following the first test run within a scenario (regardless of equipage). Six comments indicated that the preceding run had been especially easy to deal with. All six were recorded in reference to the final run with a scenario.

GENERAL COMMENTS ABOUT DATA LINK.

A total of 17 comments were received regarding the general impact of Data Link on the ATC task. All of these were positive comments. The most common remarks referred to reduced frequency congestion, reduced requirements for responding to pilot check-in and for monitoring for voice responses to clearances, general workload reduction and more available time, and reduced chance for pilot interpretation errors. Other comments noted the high frequency with which the subject was able to employ Data Link.

SERVICE DESIGNS.

One subject noted that the Data Link equipage symbologies in the Full Data Block (FDB) may be confusing to controllers. He indicated that the diamond symbol may be misinterpreted as a "flat track" symbol, and that the hourglass appeared similar to a formerly used symbol denoting that another sector has track control and hold.

Two subjects indicated that an improved display may enhance the detectability by a receiving controller of the change from the diamond to the hourglass symbol (after a TOC). As noted by one of the subjects, under the current voice system the pilot check-in cues the controller that the aircraft is ready to receive instructions. In the Data Link system, the controller must monitor closely for the change to the hourglass symbol. Thus, this change in Data Link eligibility state may require a more obvious and salient signal to prevent excessive task demands on the controller.

One controller was particularly concerned with the "FAIL" message in the FDB. Since this message does not discriminate among a pilot "UNABLE" response, a failed technical acknowledgement (NAK) or a timeout, he found himself attempting to repeat uplinks when, in fact, the pilot had unabled the clearance. He suggested eliminating the UNABLE pilot Data Link response and developing a standard procedure requiring pilots to make a voice radio call if incapable of complying with a controller's instruction.

A final recommendation was provided by a controller who indicated that he sometimes forgot whether he had pressed the appropriate key to uplink an altitude (S). He felt that such confusions would be reduced by increasing the duration of the "WILCO" display presentation. A second controller also noted the need for more visual feedback after an altitude assignment to reduce the monitoring demands of the task. It should be noted that this issue may be resolved by a design modification which was in progress during the study. This modification will present an alternating display of the original and newly assigned altitudes until a pilot WILCO is received.

In general, the problems noted during the test bed sessions were few in number. However, they tended to center around needed reductions in the visual monitoring demands of completing Data Link transactions.

EFFECTS OF DATA LINK EQUIPAGE LEVEL.

The SWAT data indicated that there were no significant differences in workload between the 70 and 20 percent levels of aircraft equipage. This finding was supported by controller comments. Four remarks were recorded in reference to this variable. All noted that neither low nor high densities of equipped aircraft had a negative impact on the controller.

EXTENDED DATA LINK DELAYS.

The workload data revealed no difference between normal and extended Data Link delays. This result was also supported by controller remarks. Four subjects commented on delay effects. All indicated that they did not feel the extended delay had a significant impact on their performance.

USE OF VOICE RADIO WITH DATA LINK EQUIPPED AIRCRAFT.

Three subjects commented that they had occasionally used radio contacts with equipped aircraft. In all cases, these subjects noted that the reversion to voice was made only during time-critical situations when rapid compliance was required. None of the subjects reported problems in shifting between voice and data link as required by availability of the link or by time constraints.

FREE TEXT.

Although not explicitly instructed to do so, several subjects indicated that they had used the free text service to issue control instructions. Two subjects noted that they had used free text successfully for heading changes. However, as expected, one subject indicated that free text required excessive keyboard inputs for regular use. One subject also noted that he mistyped a free text control instruction which caused pilot confusion. A third subject commented on the high probability of controller and pilot errors when free text was used to issue ATC instructions. These remarks indicate that the lack of error checking and high input demands make free text primarily suitable for its originally intended purpose of emergency communications or for use by a "D" controller. The subject's spontaneous use of free text for ATC instructions, and their subsequent discovery of its unsuitability for this purpose, also appears to explain the lower effectiveness and preference ratings received by this service compared to the other three data link functions tested.

ATC INCIDENTS.

An Incident Comments form was available to the subjects and the facilitator controllers after each test run to record any observed events which may have impacted the overall safety and efficiency of ATC. No incidents were reported on any of the trials which would indicate a difference in ATC performance or effectiveness between current, baseline conditions and the Data Link conditions.

SWAT WORKLOAD RATING INFORMATION

Attached to this appendix are instructions that were issued to the controller subjects prior to actual testing.

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2. Talotta, et al., <u>Controller Evaluation of Initial Data Link Air Traffic Control Services: Mini Study 1</u>, FAA Technical Center, 1988.

3. Talotta, et al., <u>Controller Evaluation of Initial Data Link Air Traffic Control Services: Mini Study 2</u>, FAA Technical Center, 1989.

ATTACHMENT

SWAT WORKLOAD RATING INSTRUCTIONS

A major goal of this study is to obtain expert opinions from air traffic controllers about the usefulness of Data Link for providing a selected group of ATC services. While we will be asking you for a wide variety of comments during the study, a major focus will be the quantitative data that we collect about controller workload from a rating scale that you will be asked to complete after each test run in the simulation facility. The purpose of this document is to familiarize you with the scale that will be used to make your workload ratings, and to describe a special procedure that we will ask you to perform which will help us to interpret your ratings on the scale. The material presented here will be reviewed in a briefing that you will receive before we start the simulation runs.

WORKLOAD RATINGS.

After each test run you will be asked to complete a simple rating scale that measures the level of workload that you actually experienced while controlling traffic during the run. The scale that we will be using for the workload ratings is known as Subjective Workload Assessment Technique SWAT. SWAT was developed as a method for collecting quantified data on how hard a human operator has to work in accomplishing his job duties using different procedures, equipment, etc., to perform them.

If you examine the scale in figure 1 you will notice that SWAT defines workload in terms of a combination of three different dimensions that contribute to the subjective feeling of "working hard." A workload rating in SWAT is accomplished by selecting a "1," "2," or "3" on EACH of the three scales representing the dimensions of TIME LOAD, MENTAL EFFORT, and PSYCHOLOGICAL STRESS LOAD.

Each of these dimensions and their levels are described below:

TIME LOAD.

Time Load refers to the fraction of the total time that you are busy. When Time Load is low, sufficient time is available to complete all of your mental work with some time to spare. As Time Load increases, spare time drops out and some aspects of performance overlap and interrupt one another. This overlap and interruption can come from performing more than one task or from different aspects of performing the same task. At high levels on Time Load, several aspects of performance often occur simultaneously, you are busy, and interruptions are very frequent.

Time Load may be rated on the three-point scale below:

TIME LOAD

1. Often have spare time. Interuptions or overlap among activities occur infrequently or not at all.
2. Occasionally have spare time. Interuptions or overlap among activities occur frequently.
3. Almost never have spare time. Interuptions or overlap among activities are very frequent or occur all the time.

MENTAL EFFORT LOAD

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.
2. Moderate conscious mental effort or concentration required. Complexity of activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention is required.
3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD

1. Little confusion, risk, frustration or anxiety and can easily be accomodated.
2. Moderate stress due to confusion, frustration or anxiety. Noticeably adds to workload. Significant compensation is required to maintain adequate performance.
3. High to very intense stress due to confusion, frustration or anxiety. High to extreme determination and self-control required.

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1. Often have spare time. Interruptions or overlap among activities occur infrequently or not at all.

2. Occasionally have spare time. Interruptions or overlap among activities occur frequently.

3. Almost never have spare time. Interruptions or overlap among activities are very frequent, or occur all the time.

MENTAL EFFORT LOAD.

As described above, Time Load refers to the amount of time one has available to perform a task or tasks. In contrast, Mental Effort Load is an index of the amount of attention or mental effort required by a task regardless of the number of tasks to be performed or any time limitations. When Mental Effort Load is low, the concentration and attention required by a task is minimal and performance is nearly automatic. As the demand for mental effort increases due to task complexity of the amount of information which must be dealt with in order to perform adequately, the degree of concentration and attention required increases. High Mental Effort Load demands total attention or concentration due to task complexity or the amount of information that must be processed.

Mental Effort Load may be rated using the three-point scale below:

1. Very little conscious mental effort or concentration required. Activity is almost automatic, requiring little or no attention.

2. Moderate conscious mental effort or concentration required. Complexity or activity is moderately high due to uncertainty, unpredictability, or unfamiliarity. Considerable attention required.

3. Extensive mental effort and concentration are necessary. Very complex activity requiring total attention.

PSYCHOLOGICAL STRESS LOAD.

Psychological Stress Load refers to the contribution to total workload of any conditions that produce anxiety, frustration, or confusion while performing a task or tasks. At low levels of stress, one feels relatively relaxed. As stress increases, confusion, anxiety, or frustration increase and greater concentration and determination are required to maintain control of the situation.

Psychological Stress Load may be rated on the three point scale below:

1.   Little confusion, risk, frustration, or anxiety exists and can be easily accommodated.

2.   Moderate stress due to confusion, frustration, or anxiety noticeably adds to workload.   Significant compensation is required to maintain adequate performance.

3.   High to very intense stress due to confusion, frustration, or anxiety.   High to extreme determination and self-control required.

Each of the three dimensions just described contribute to workload during performance of a task or group of tasks. Note that although all three factors may be correlated, they need not be.   For example, one can have many tasks to perform in the time available (high Time Load) but the tasks may require little concentration (low Mental Effort Load).   Likewise, one can be anxious and frustrated (high Stress Load) and have plenty of spare time between relatively simple tasks. Since the three dimensions contributing to workload are not necessarily correlated, please treat each dimension individually and give independent assessments of the Time Load, Mental Effort Load, and Psychological Stress Load that you feel were imposed during each test run.

The form that you will be using to make your SWAT ratings during the Data Link test session is shown in figure 2.   Note that the descriptions for each level of time, effort, and stress load have been removed to save space.   Should you need to review these descriptions during testing, a copy of the full scale will be available at all times.

SWAT SCALE DEVELOPMENT CARD SORT.

Now that you are familiar with rating scale that will be used during the Data Link Test sessions, there is one last procedure that must be completed before testing can begin.   This procedure is a card sorting task that will allow us to interpret your SWAT workload ratings.   We will be asking to do this task during the briefing that will take place to review the rating scales.

One of the most important features of SWAT is its unique scoring system.   The developers of SWAT recognized that different people have different conceptions of how the time, effort and stress dimensions combine to produce an overall impression of low and high workload.   Because of these differences, a special card sorting procedure is used in SWAT to define a distinctive workload scale for each person.   This individualized scale greatly improves our ability to accurately interpret the actual workload ratings that you will making during the test sessions.

In order to develop your individual scale, we need information from you regarding the amount of workload that you feel is produced by

NAME ------------------------------

SECTOR ------------------------------

TEST CONDITION:
 SCENARIO   1 ___   2 ___
 EQUIPAGE LEVEL   20% ___   70% ___
                   0% (VOICE ONLY) ___

Rate the workload that you _actually_ experienced while
controlling air traffic during this test run by placing
an "X" below one of the numbers on the TIME, EFFORT
and STRESS scales.

	(Low) 1	2	(High) 3
TIME LOAD	-------	-------	-------
MENTAL EFFORT	-------	-------	-------
STRESS	-------	-------	-------

COMMENTS:

various combinations of the three levels of the time, effort, and stress dimensions. We get this information by having a person rank order a set of cards. Each card contains a different combination of the levels of Time Load, Mental Effort Load, and Stress Load. Since there are three dimensions, and each dimension has three levels, there are 27 cards in the deck that you will be sorting. Your job will be to sort the cards so that they are ranked according to the level of workload represented by each card. Thus, the first card in the deck will represent the lowest workload and the last card will represent the highest workload.

In completing your card sorts, please consider the workload imposed on a person by the combination represented in each card. Arrange the cards from the lowest workload condition through the highest condition. You may use any strategy you choose in rank ordering the cards. One strategy that proves useful is to arrange the cards into a number of preliminary stacks representing "High," "Moderate," and "Low" workload. Individual cards can be exchanged between stacks, if necessary, and then rank ordered within stacks. Stacks can then be recombined and checked to be sure that they represent your ranking of lowest to highest workload. However, the choice of strategy is up to you and you should choose the one that works best for you.

There is no "school solution" to this problem. There is no correct order. The correct order is what, in your judgement, best describes the progression of workload from lowest to highest for a general case rather than any specific event. That judgement differs for each of us. The letters you see on the back of the cards are to allow us to arrange the cards in a previously randomized sequence so that everyone starts with the same order. If you examine your deck you will see the order on the back runs from A through Z and then ZZ.

Please remember:

1.   The card sort is being done so that a workload scale may be developed for you. This scale will have a distinct workload value for each possible combination of Time Load, Mental Effort Load, and Psychological Stress Load. The following example demonstrates the relationship between the card sort and the resulting workload scale:

TIME	EFFORT	STRESS	WORKLOAD SCALE
1	1	1	0.0
.	.	.	.
.	.	.	.
.	.	.	.
.	.	.	.
3	3	3	100.0

Note that other than the fact that a 1-1-1 will always represent the lowest workload and that a 3-3-3 will always represent the highest workload, the remaining cards could occur in a number of orders. Your order will depend on how you weight the importance of Time, Effort, and Stress dimensions.

2. When performing the card sorts, use the descriptors printed on the cards. Please remember not to sort the cards based on one particular task (such as controlling air traffic). Sort the cards according to your general view of workload and how important you consider the dimensions of Time, Mental Effort, and Psychological Stress Load to be.

3. During the Data Link test runs, you will accomplish the desired task. Then, you will provide a SWAT rating based on your opinion of the mental workload that you experienced while performing the task. This SWAT rating will consist of one number from each of the three dimensions. For example, a possible SWAT rating is 1-2-2. This represents a 1 for Time Load, a 2 for Mental Effort Load, and a 2 for Psychological Stress Load.

4. When doing the sorting task, we are not asking for your preference concerning Time, Mental Effort, and Psychological Stress Load. Some people may prefer to be "busy" rather than "idle" in either the Time Load, Mental Effort Load, or Psychological Stress Load dimension. We are not concerned with this preference. We need information on how the three dimensions and the three levels of each one will affect the level of workload as you see it. You may prefer a 2-2-2 situation instead of a 1-1-1 situation. However, you should still realize that the 1-1-1 situation imposes less workload on you and leaves a greater reserve capacity.

The sorting will probably take 30 minutes to an hour. Please feel free to ask questions at any time.

APPENDIX C

ANALYSIS OF ATC DATA LINK
AND VOICE ACTIVITY

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LIST OF ILLUSTRATIONS

INTRODUCTION

During the operational evaluation of the initial Air Traffic Control (ATC) Data Link services, various types of data were recorded by the computer systems used in the tests. The data were collected and reduced using data reduction tools available on the Host Computer System and other data reduction methods developed by MITRE personnel. The reduced data were then input to a graphics package to produce a set of graphical results depicting Data Link metrics.

The Data Link data analysis results provided herein consist of a number of metrics presented on graphs that provide information about specific aspects of the controller Data Link and voice communication message activity which took place during the test runs. The data analysis results are divided into three sections. The first section, "Data Link Activity Results," reports on the Data Link activity which took place during the testing. The second part, "Voice Communications Results," describes the effect Data Link had on voice communications, while the third section, "Data Link and Voice Message Results," compares the message activity of voice and Data Link.

The sources of the data used to produce the metrics were the Host Computer System, which logged all Data Link activity, and the AMECOM FAA Technical Center Communication Switching System, which recorded all controller voice communications. Data pertaining to pilot voice communications were not available; therefore, all data reported for voice communications applies only to controller operations.

Two different scenarios were used in the evaluations, each having a 0, 20, and 70 percent Data Link-equipage level. The sequence of the runs, the scenario used, and the Data Link-equipage are provided in figure C-1. (Please note: Only test runs that were used for data reduction are included in this chart. Other test runs conducted in the operational evaluation were intended for special study of specific Data Link aspects and were not appropriate for this analysis).

The order of the runs and the Data Link-equipage are presented because of the influence they had on the data collected. An ordering effect (i.e., which order the Data Link-equipage scenario was presented) became significant as a result of a learning curve experienced by the controllers. During the first run of a scenario the controllers were unfamiliar with the traffic pattern, but, by the third run with the same scenario, the controllers knew what to expect, and, therefore, did not need to communicate with the aircraft as frequently. This effect is apparent in some of the data and should be noted and factored into the interpretation of the results. Additionally, due to the varied lengths of the test runs, all data collected are based on the same half-hour interval (System

Day	Run Number*	Scenario Number	Data Link Equipage (%)
1	1	1	0
1	2	1	70
1	3	1	20
1	5	2	20
1	6	2	70
1	7	2	0
2	1	1	20
2	2	1	70
2	3	1	0
2	5	2	0
2	6	2	70
2	7	2	20

*NOTE: Runs 4 and 8 are not included since they were used for special Data Link testing.

FIGURE C-1.   SEQUENCE OF DATA LINK TEST RUNS

Time - 12:55 to 13:25). This time interval was chosen because the shortest test run ended at approximately 13:25. Therefore, the data collected represents the same time intervals in the test runs.

DATA LINK ACTIVITY RESULTS

This group of results measures the Data Link activity. These results contain four figures which represent the average Data Link activity and traffic volume which took place during the test runs listed in figure C-1. The average consists of the message activity and traffic volume during the eight Data Link runs at 20 and 70 percent Data Link-equipage divided by 8. For example, all uplinks for the eight Data Link runs are added together and divided by 8 to give the 102 uplinks in the bar chart in figure C-2.

Figure C-2 presents the Uplinks, Will Complies (WILCOs), No Technical Acknowledgements (NAKs), and No Pilot Responses or Pilot Unables which are both denoted by FAIL (i.e., a FAILed response from the pilot). The bar chart on the left contains the average number of messages in each of the above categories, while the pie chart on the right shows the WILCOs, NAKs, and FAILs as a percentage of uplinked messages.

On the average, 102 Data Link messages were uplinked during the half-hour interval of each test. Also, from the pie chart, 91 percent of all Data Link messages were WILCOed by pilots, and only 4 percent of the messages were either "UNABLED" by the pilot, or not responded to within the 40-second pilot response timeout period* (e.g., FAIL messages).** This figure appears impressive with respect to the number of times a controller must reissue instructions by voice because of garbled communications over the radio channels. The results indicate that Data Link messages are sent to pilots with a low repeat rate and that Data Link message response time occurs within an acceptable time period.

With respect to NAKed messages, the VAX computer, acting as the Data Link processor, generated the NAK's randomly during the tests. This was done to simulate equipment failures which might take place during actual field implementation. The VAX was programmed to generate NAK's at a 5 percent rate (this rate is well above the rate expected in actual implementation, but was set to 5 percent during the tests so an analysis could be performed on controller reaction to this situation); the 5 percent NAK rate was verified in the analysis.

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*The 40-second pilot response timeout period includes uplink time, pilot recognition and response time, and downlink time.

**During the operational evaluation, simulation pilots were used for the majority of aircraft flying in the scenarios. (Only two aircraft simulators rate needs to be studied with a greater percentage of pilots flying real aircraft.)
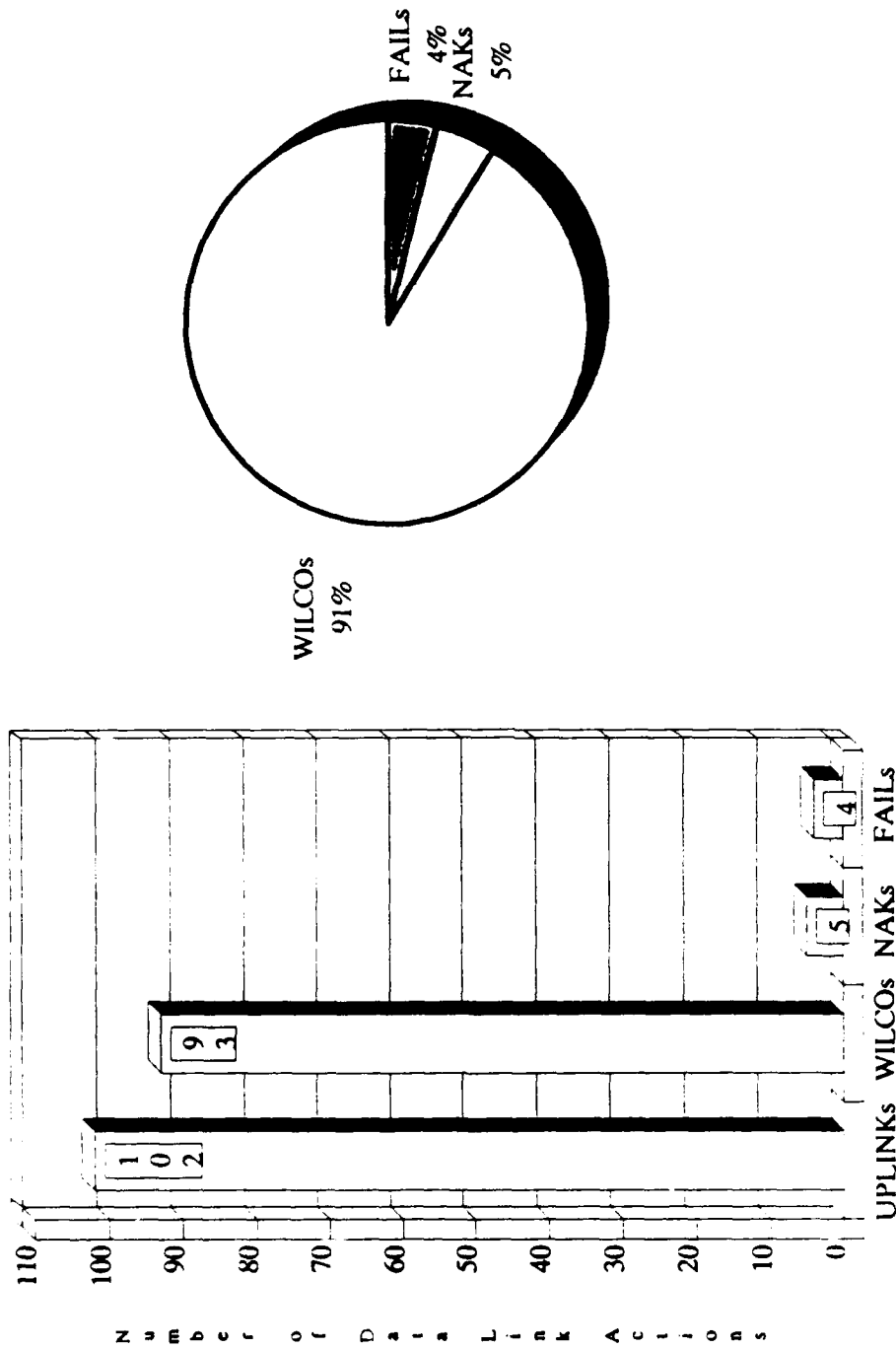
FAILs
4%

NAKs
5%

WILCOs
91%

UPLINKs   WILCOs   NAKs   FAILs

110
100
90
80
70
60
50
40
30
20
10
0

N u m b e r   o f   D a t a   L i n k   A c t i o n s

*NOTE: The average consists of the sum of the 8 Data Link runs at 20% and 70% Data Link Equipage divided by 8

FIGURE C-2.   AVERAGE DATA LINK ACTIVITY

Figure C-3 presents the average Data Link activity which took place for each Data Link service or function (these numbers represent the number of uplinked messages for each service or function regardless of the downlink response). The Data Link services and functions tested in the operational evaluation were: Altitude Assignment (AA), Interim Altitude via Menu Text (MT), Transfer of Communication (TC), and Free Text (FT). The menu text figures represent interim altitudes via the menu text function. Since menu text was used for the sole purpose of uplinking interim altitudes in the operational evaluation, no other menu text figures are given.

The bar chart provides the average number of uplinks per service or function over the half-hour interval. In addition, the percentage use of each of the capabilities is given in the pie chart. For example, on the average, the Transfer of Communication service represented 29 percent of all uplink messages. Also, from this chart the combination of Altitude Assignment and Interim Altitude via Menu Text represented 57 percent of all uplinks.

The third chart in this group of results (figure C-4) displays the Data Link activity by Uplinks, WILCOs, NAKs, and FAILs during 3-minute intervals during the tests. This provides a look at the Data Link activity during specific times during the test runs.

The traffic volume in the operational evaluation scenarios varied from sector to sector, but gradually increased for all sectors between the time interval 12:55 to 13:25 from which the data were taken (see figure C-5). The Uplinks and their responses presented in figure C-4 increase at approximately the same rate as the traffic volume presented in figure C-5. Therefore, the data show that Data Link can be used with the same effectiveness during low and high traffic loads.

VOICE COMMUNICATIONS RESULTS

The voice communication results are based on digital recordings of the controller voice activity. The computer systems used in the evaluation did not have the capability to record pilot voice communications, therefore, these results are based solely on controller voice communications. Even though the pilot voice activity is not included in the results, the controller voice communications can provide a good indication of the reduction in activity on the radio channels as a result of the initial Data Link services.

The voice communication data provides an analysis on the number and duration of controller voice messages. Figures C-6 and C-7 report on the reduction in the number of messages, while figures C-8 and C-9 provide data on the reduction in duration of voice messages during the half-hour interval.
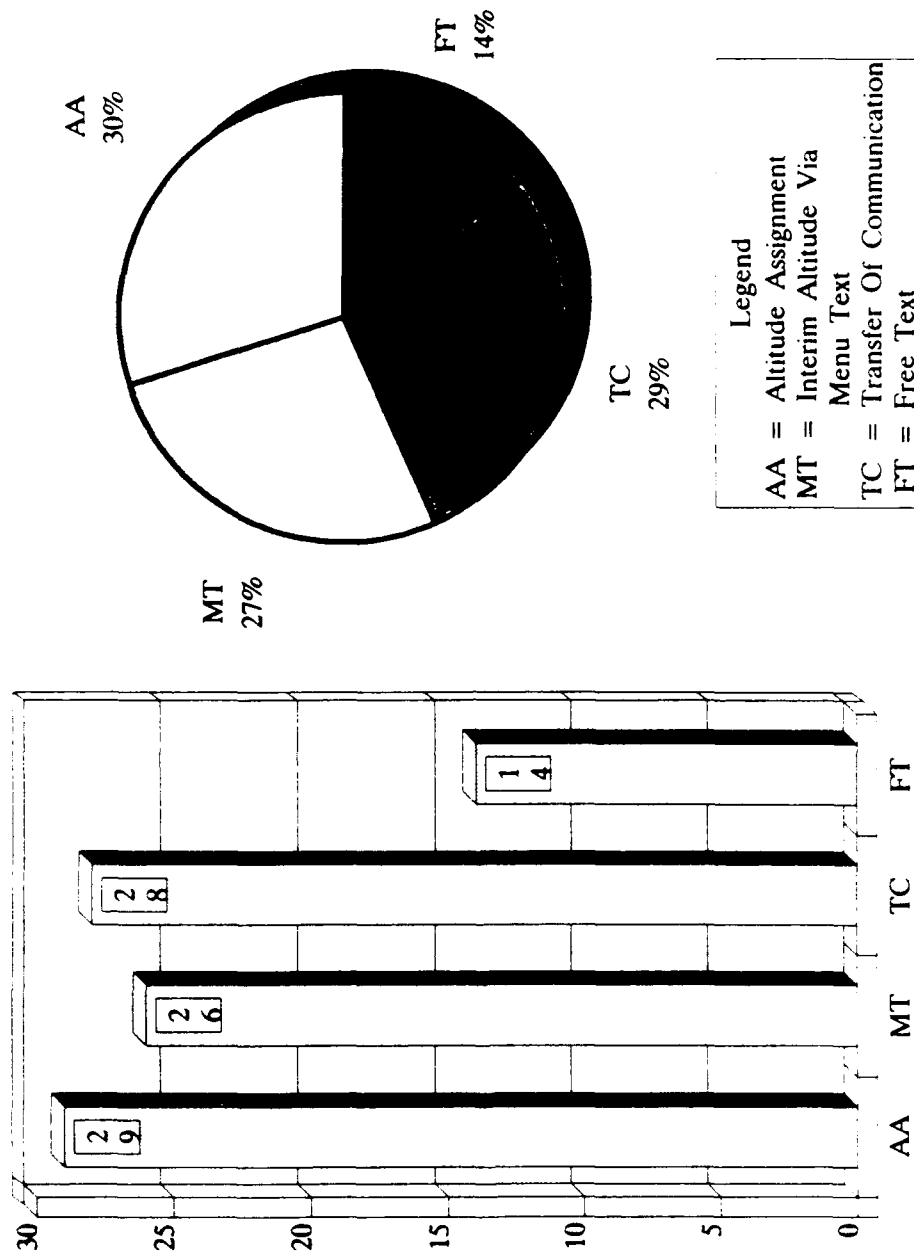
FIGURE C-3. AVERAGE DATA LINK ACTIVITY BY SERVICE/FUNCTION

FIGURE C-4.   AVERAGE DATA LINK ACTIVITY, 3-MINUTE INTERVALS
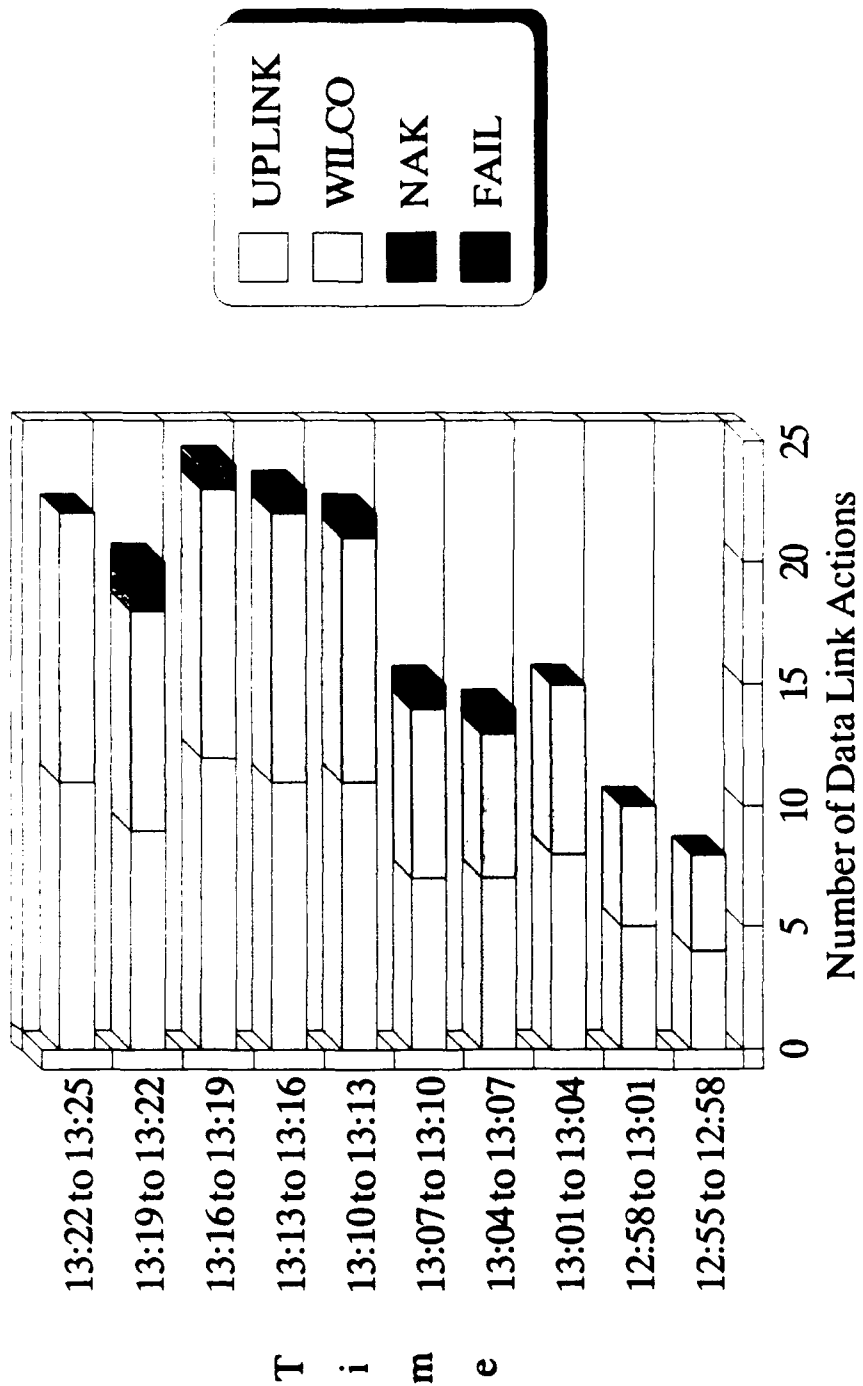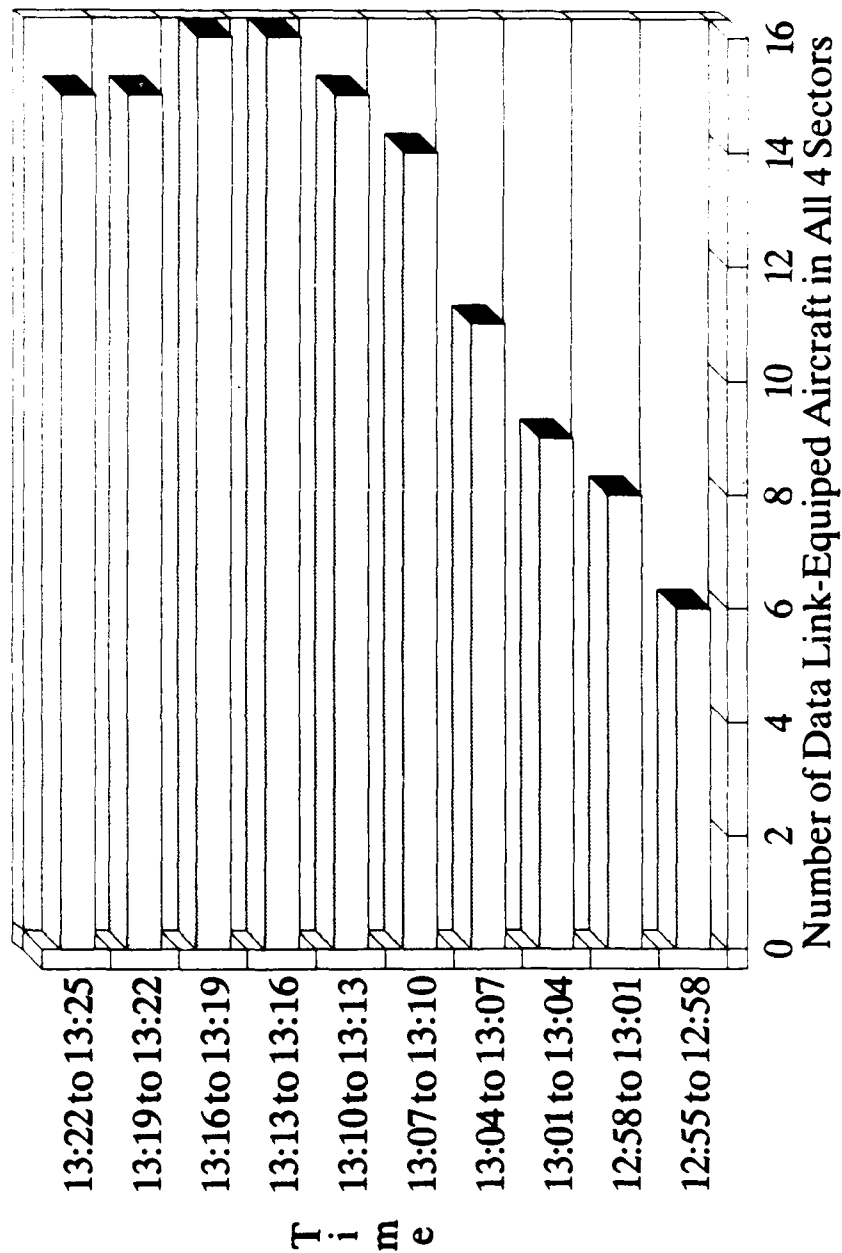
*NOTE: The average during each interval consists of the sum of the 8 Data Link runs at 20% and 70% Data Link Equippage divided by 8.

FIGURE C-5.   AVERAGE NUMBER OF DATA LINK AIRCRAFT, 3-MINUTE INTERVALS

FIGURE C-7.   REDUCTION IN NUMBER OF VOICE MESSAGES

*NOTE The average consists of the sum of the number of voice messages during each of the Data Link Equipage scenarios divided by 4 during the half hour interval

FIGURE C-6.   AVERAGE NUMBER OF VOICE MESSAGES

FIGURE C-9.   REDUCTION IN DURATION OF
             VOICE MESSAGES

FIGURE C-8.   AVERAGE DURATION OF VOICE
             MESSAGES

Figure C-6 presents the average number of voice messages during the 0, 20, and 70 percent Data Link-equipage scenarios. The average represents the sum of the number of controller voice messages during each run at each Data Link-equipage level divided by 4 (i.e., there were four 0 percents, four 20 percents, and four 70 percents runs in the data collection, see figure C-1). For example, during all of the 0 percent Data Link-equipage scenarios tested, the controller issued an average of 422 voice messages during the half-hour interval.

Figure C-7 compares the number of voice messages during the different equipage runs. The numbers given show the reduction in controller voice messages using two levels of Data Link-equipage. From the data 41 percent of voice messages (i.e., the number of messages) were eliminated when 70 percent of the aircraft were Data Link-equipped. (The 41 percent figure is based on the number of voice messages during the 70 percent Data Link-equipage scenario as a percentage reduction in the number of voice messages in the 0 percent Data Link-equipage scenario.)

Figure C-8 provides the average duration of the voice messages during each of the 0, 20, and 70 percent Data Link-equipage scenarios. These numbers represent the time, in seconds, the controllers were on the radio frequencies during the half-hour interval. The average was computed the same as in figure C-5, except the duration of the messages was averaged instead of the number of messages. For example, on the average, during the 20 percent Data Link-equipage scenarios tested, the controllers were on the radio frequencies for a total of 1046 seconds.

Figure C-9 compares the voice messages during the different equipage runs. The graph shows the reduction in the total duration of voice messages as a result of the two Data Link-equipages. From the data, 45 percent of the voice communications (e.g., the duration of the communications) were eliminated when 70 percent of the aircraft were Data Link-equipped. (The 45 percent figure is based on the duration of voice messages during the 70 percent Data Link-equipage scenario as a percentage reduction in the duration of voice messages in the 0 percent Data Link-equipage scenario.)

The data given for the 20 percent Data Link-equipage seems inconsistent with the effect Data Link should have on the voice communications. From the data in figure C-9 it appears that a 20 percent Data Link-equipage reduces voice communications by 28 percent. These are the numbers reported by the data, but the 20 percent runs were heavily influenced by the ordering effect. The ordering effect is the reduction in communications needed with the aircraft as the controller becomes familiar with the scenario. Since the controller knows where and when the aircraft are present in the scenario, by the third run he no longer needs to issue ATC instructions as often.

From figure C-1 the 20 percent runs were presented to the controllers either first or third, while the 70 percent runs were always run second. Since the 70 percent runs were always run second, the number of times the 0 percent runs were either first or third were equal, thus, eliminating the ordering effect on the 70 percent runs when taking the average. But the 20 percent runs did not experience this. Therefore, it is recommended that in future testing, the ordering effect be reduced by improving controller familiarization with the scenario or by making more test runs to balance out the effect.

In addition, to fully understand the impact of Data Link on voice communications, future tests need to be performed with other Data Link equipages. But, from the data collected thus far, it is apparent that Data Link will have a significant impact on reducing the number and duration of voice communications on the radio channels.

DATA LINK AND VOICE MESSAGE RESULTS

Figure C-10 presents the average number of voice and Data Link messages during each of the 0, 20, and 70 percent Data Link-equipage runs. The data are presented together to show how an increase in Data Link-equipped aircraft produces a decrease in the number of voice messages.

In addition, as figure C-10 indicates, when Data Link is used, the total number of messages (voice plus Data Link) is reduced. For example, when Data Link was not used, there were 422 total messages. But, when 70 percent the aircraft were Data Link-equipped, there were only 375 total messages. An explanation of these results could be the reduction in repeat communications via voice when Data Link is used. Data Link messages need not be repeated due to misunderstandings as is the case with voice, where the message may become distorted on the radio frequency.

The data indicate that not only does Data Link reduce voice congestion on the radio channels, but also reduces the need for repeat voice communications. Additionally, Data Link affords a safer ATC system by providing clearly understood ATC messages.

Voice

Data Link

450
400
350
300
250
200
150
100
50
0

422

316

248

0

59

127

0 10 20 30 40 50 60 70

Data Link Equipage (%)
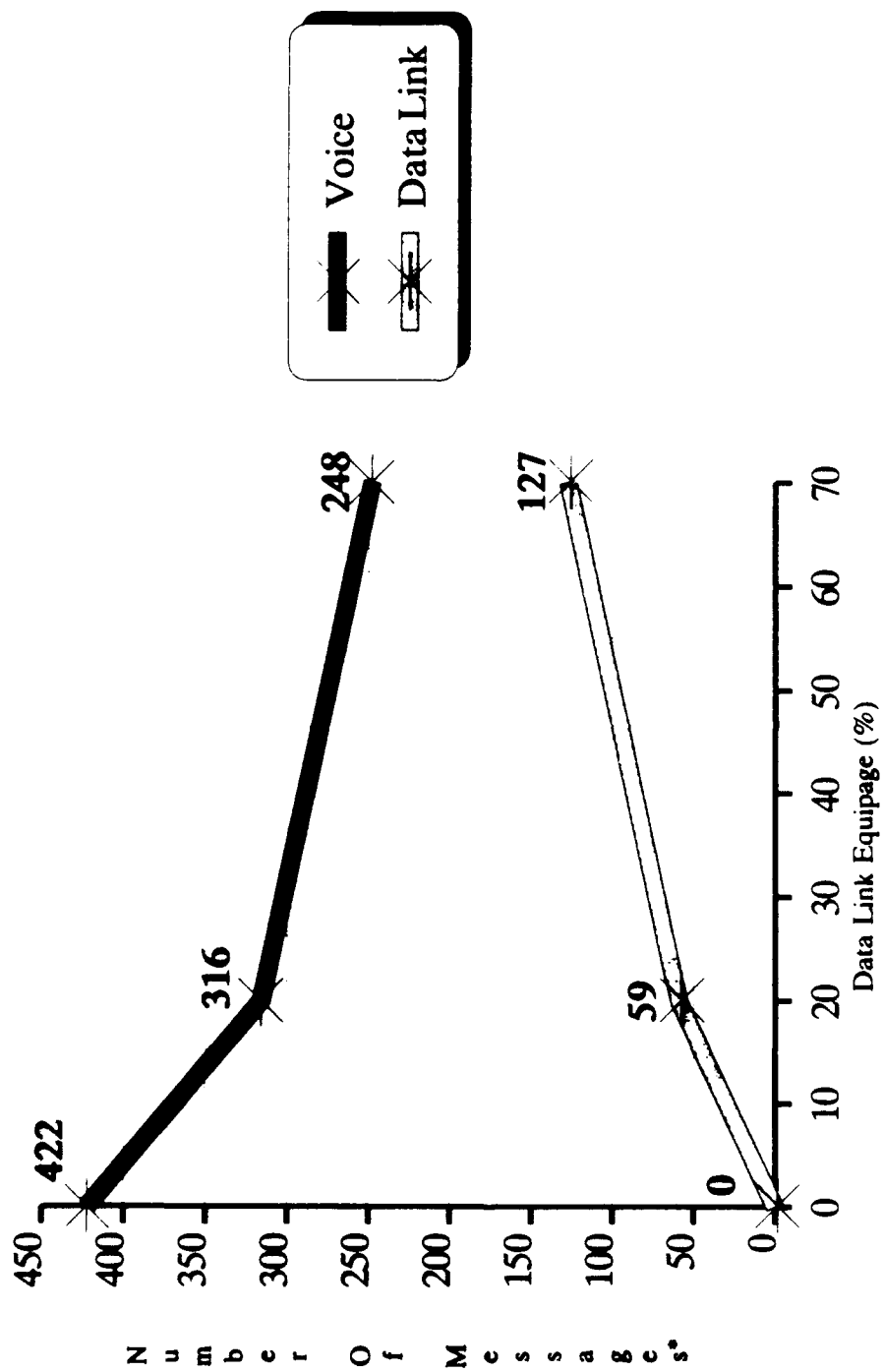
Number Of Messages*

*NOTE: The number of messages is the average message count during each of the Data Link Equipage scenarios during the half hour interval

FIGURE C-10. DATA LINK AND VOICE MESSAGES

APPENDIX D

ANALYSIS OF GROUP DISCUSSION AND DEBRIEFING DATA

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INTRODUCTION

This report analyzes the commentary offered in a structured debriefing discussion with the Air Traffic Control Specialists (ATCS's) who participated in the operational evaluation of Data Link services. In the context of the study protocol, this discussion followed an unstructured joint debriefing session that allowed some of the participating flight crews to interact with the ATCS's by teleconference.

The issues addressed in the structured debriefing were presented in a discussion guide form and handed out prior to the session. This analysis covers oral comments obtained during the session and written comments submitted on the discussion guide forms. Beginning with a background section describing the participants, the report then turns to the three issue areas addressed in the discussion guide: operational procedures, displays and inputs, and controls.

PARTICIPANTS

The eight ATCS's who operated control positions in the operational evaluation reported background information on their air traffic control (ATC) experience and expertise. In all, six en route facilities were represented: Memphis Center, Washington Center, Fort Worth Center, Anchorage Center, Miami Center, and Cleveland Center. All but two of the ATCS's were current full performance level (FPL) controllers. FPL experience ranged between 2.5 and 33 years with a mean of 11.21 years. Three of the seven also reported pilot experience (mean of 6.7 years). Other related expertise reported by the ATCS's included an airspace and procedures specialist, an Air Force ATCS, and an FAA academy instructor.

Apart from the ATCS's who operated the control positions in the operational evaluation, the en route members of the FAA Air Traffic Data Link Validation Team (ATDLVT) also attended the discussion session. The ATDLVT members participated primarily as facilitators throughout the discussion session to clarify issues and correct misunderstandings.

OPERATIONAL PROCEDURES

Operational procedures was the first area taken up in the debriefing. This area includes both controller-pilot procedures and controller-computer procedures. Four themes emerged from the analysis of the comments on procedures: control of message transmission and content, exception handling and display feedback, allocation of Data Link tasks within the radar team, and refinements and enhancements to Data Link capabilities.

CONTROL OF MESSAGE TRANSMISSION AND CONTENT.

According to the ATCS's, operational procedures for the initial Data Link, services should contain specific guidelines for control of Data Link message transmissions. Under normal circumstances, the controller should wait for operational acknowledgement of one Data Linked instruction before transmitting a second instruction to the same aircraft. This form of control was deemed especially important for the transfer of communication (TOC) message because of the associated transfer of Data Link communication eligibility. There was good agreement among the ATCS's that while the TOC was underway no other transmissions should be initiated to the aircraft. For the most part, this procedure applies to all other ATC instructions; however, the ATCS's recognized that there may be special situations (e.g., onboard emergency) where it becomes necessary to transmit additional instructions without waiting for an operational acknowledgement.

On the topic of transmission control, there was some discussion of implementing an automated control over message transmission at least for the TOC message. As discussed by the ATCS's, this automation would effectively lock-out all other transmissions to an aircraft while a TOC was pending (i.e., sent but not yet acknowledged). However, at this stage in the development of Data Link it would seem prudent to leave such a decision to the controller. An automated procedure could have far reaching implications for the service designs. A number of related issues, such as impact on the Data Link eligibility override capability, should be investigated before an automated control over message transmission is recommended. For now, a more appropriate compromise would be an automated notification to the controller attempting transmission that the aircraft has a pending transaction; and if the pending transaction were a TOC, the automation could also require explicit confirmation (using a distinctive confirm key) by the controller before transmitting the new instruction.

There was also some discussion of operational procedures to control message content. The ATCS's agreed that explicit guidelines should be adopted to restrict the use of free text messages. By definition, free text messages should be reserved for communication needs beyond the capabilities provided by the available ATC services. Use of free text is labor intensive and can be error prone. As a rule, the ATCS's recommended that this method of message composition not be used for control instructions.

EXCEPTION HANDLING AND DISPLAY FEEDBACK.

A second theme that emerged in the discussion of operational procedures concerned handling of exceptions to normal Data Link transactions and the presentation of feedback to controllers on the status of exceptions. An exception is defined as any transaction

that is not completed with a WILCO acknowledgement by the flight crew. During the operational evaluation, controller procedures and display feedback were premised on an assumption that flight crews would contact the controller on the voice channel if they were unable to comply with an uplinked control instruction. As it turned out, the participating flight crews often downlinked their UNABLE responses without an accompanying voice call.

The discussions on exception handling identified two recommendations to support exception handling. First, controller and pilot procedures need to be coordinated. So far, use of voice to work out an alternative if the pilot is unable to comply with an instruction appears to be most acceptable as a standard procedure. Second, controller display feedback needs to differentiate among different exception conditions: pilot UNABLE response, no pilot response within message timeout parameter, and message delivery failure. An UNABLE response option for flight crews will be required for Data Link communication, if only to update the automated systems in the air and on the ground that the last instruction is not the current agreement. The downlinked UNABLE could, in fact, be processed somewhat like the WILCO response by the ground automation; clearing the controller's Data Link status displays, but also restoring the data block and/or data base to reflect the previous values. Further discussion and analysis of the UNABLE response is needed before suitable automated processing can be specified.

ALLOCATION OF DATA LINK TASKS WITHIN THE RADAR TEAM.

A third theme from the discussion of Data Link procedures was radar associate controller tasking. Recently, the concept of a radar team for operational position staffing was formally introduced with the development of the Operational Position Standards (FAA 7220.2). This concept provides flexibility in the assignment of tasks to the team of controllers who staff an operational position (radar sector). During the operational evaluation and in the previous mini studies, a division of Data Link tasking between the radar position and the radar associate position was mentioned repeatedly. In particular, the ATCS's felt that responsibility for TOC's would blend smoothly with the radar associate's current tasking. In addition, computer entries required for composition of lengthy Data Link messages (route amendments) could also be performed by the radar associate. Since all of the test results converge on this recommendation, procedures and software accommodating the above division of tasking should be presented to the ATDLVT for inclusion in future tests.

REFINEMENTS AND ENHANCEMENTS TO DATA LINK CAPABILITIES.

Under the fourth theme, Data Link refinements and enhancements, a number of comments on functions and procedures are grouped for discussion. Several comments concerned the TOC service:

1. Redesign of the TOC message SENT status display for the receiving controller was recommended. Instead of the existing Data Link status list entry on the receiving controller display, it was recommended that only the data block display of TOC message SENT symbology should be presented to the receiving controller.

2. Implementation of an automatic TOC option was also recommended. This option has been recommended in both of the preceding mini studies; it has also been discussed at some length with the ATDLVT. There is good support for the idea and its design should be taken up with the ATDLVT for their concurrence and action.

3. A controller option to specify (in real time) the default frequency for the TOC message was recommended as was a frequency assignment service. The frequency assignment service would support outages and multiple frequency sectors by enabling the controller to transmit a message--"change to my frequency ___ ."

4. After considerable discussion, a majority opinion was reached on the issue of voice check-in: a voice check-in on frequency is deemed acceptable as a transitional procedure when Data Link is first introduced. Notwithstanding the majority opinion, there remains a strong minority opinion among the ATCS's that this transmission should be phased out as soon as flight crew confidence or frequency confirmation via advanced avionics permits.

A number of comments concerned refinement of the existing interim altitude menu and additional capabilities for menu message selection and transmission. The existing design for the interim altitude menu has two special use menu items: "R" and "Z." The special use menu item "R" is called requested altitude. Selection of menu item "R" automatically generates an altitude assignment message that contains final assigned or requested altitude currently stored in the NAS data base for the aircraft. It was recommended that this item appear in a hard altitude assignment (QZ) menu instead of the interim altitude assignment (QQ) menu.

The "Z" item, called controller-defined altitude, was intended to allow a controller with Data Link eligibility to transmit an interim altitude assignment to an aircraft after track control had been handed off to the next sector. It was to be used in situations where the controller in the next overlying/underlying sector uses the data block to coordinate with the current controller by entering the available interim altitude for the aircraft. Instead of the existing procedure where the current controller selects "Z" and composes the altitude assignment message based on the interim altitude displayed in the data block, it was

recommended that the "Z" item be redesigned to automatically compose the message. Both "R" and "Z" would then function identically except that the "R" item would generate a hard altitude assignment and the "Z" item would generate an interim altitude assignment. This modification would reduce controller inputs and the risk of input errors. It would also ensure that the altitude information displayed to the controller matches the information transmitted to the pilot.

Taken together, the above recommendations open up the possibility of further reducing controller inputs. Transmission of the current values for assigned and interim altitude could be implied actions. Selection of the QZ or QQ quick action key followed by an "S" to indicate an uplink request and the flight identification would completely specify the message content, obviating the need to enter a menu item label.

The final comment on menu messages concerned the addition of compound altitude and heading messages to the capability. Such messages are commonly required to establish departing aircraft on their routes. They are repetitious in nature and could offload many routine transmissions from the voice channel.

DISPLAYS

As in the previous studies, the ATCS's who participated in the operational evaluation reiterated the principle that to the extent possible Data Linked control instructions and their status should be presented in the full data block. In addition to the comments on exception status displays that were reviewed in the preceding section, the ATCS's also commented that the WILCO status display was removed too quickly. A display persistence parameter of 6 seconds was used in the operational evaluation, based on what were, essentially, inconclusive test results from the second mini study. Given the comments from this second group of ATCS's, it would appear that a longer (12 seconds) display persistence may be a more suitable default parameter.

Another important display issue that came up in the operational evaluation was the principle of display by exception. Again, this issue has been discussed in the earlier studies, but a consensus position was not achieved. The intent of the display by exception principle is to help manage the Data Link status list; it does not necessarily affect the data block displays. According to the ATCS's, only "FAILED" altitude transactions should have both a data block and a list presentation. A data block presentation of feedback is sufficient for normal (WILCOed) altitude transactions. By confining the list entries for altitude transactions to failed transactions, the list could be kept shorter and, thereby, simplify controller monitoring. Other suggestions for list management, such as creation of sublists for different services, have been proposed

in previous discussions. This list management issue should be referred to the ATDLVT.

On the topic of transmission control and error response feedback, the ATCS's recommended a specific display notification. Two other transmission error notifications were identified in the previous studies: "not Data Link equipped" and "not your Data Link control." Both of these notifications effectively prevent transmission of the intended message and require the controller to reconstruct an appropriate message. In the former case, the reconstructed message is addressed only to the NAS computer; in the latter case, the controller may use an eligibility override capability to enable subsequent transmissions. A third type of notification was proposed in this study: "Data Link control transfer in progress." This should be presented to the controller who attempts to transmit a message to an aircraft while a TOC is pending. In addition, an explicit controller confirmation may be desirable to implement a transmission while the TOC is pending.

INPUTS AND CONTROLS

On the topic of Data Link controls, the ATCS's gave two recommendations. First, the display of the menu message list should be under a separate control from display of the message status list. Second, a capability to transmit the TOC message by trackball selection should be provided. Both recommendations have been cited in previous studies and design proposals should be presented to the ATDLVT.

Finally, the ATCS's recommended that the initial Data Link capability should be broadened to include a full range of control instructions. Aside from altitude and frequency assignments, heading and route and speed and delay instructions were recommended as initial Data Link services.

ATTACHMENT

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1   OPERATIONAL EVALUATION OF DATA LINK
                           SERVICES
                  DEBRIEFING DISCUSSION GUIDE

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****************************************************************
```
2   PERSONAL INFORMATION

NAME: _____   FACILITY: _____

*ATC EXPERIENCE:

(REPORT ALL RELEVANT EXPERIENCE; CIRCLE YOUR CURRENT POSITION)

_____FPL CONTROLLER   _____ YEARS

_____FIRST LEVEL SUPERVISOR   _____ YEARS

_____OTHER (SPECIFY) _____

*PILOT EXPERIENCE   _____NO   _____YES   _____YEARS

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3   OUTLINE

*   OPERATIONAL PROCEDURES

*   DISPLAYS

*   INPUTS/CONTROLS

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****************************************************************
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4   OPERATIONAL PROCEDURES

*COMMENTS/RESERVATIONS CONCERNING USE OF THE DATA LINK ATC SERVICES
 IN A FULL DATA LINK EQUIPAGE ENVIRONMENT:

ALL SERVICES_____
_____
TRANSFER OF COMMUNICATION_____
_____
ALTITUDE ASSIGNMENT (QZ) _____
_____
INTERIM ALTITUDE ASSIGNMENT (QQ) _____ _____
_____
INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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5   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING USE OF DATA LINK ATC SERVICES
 IN MIXED EQUIPAGE ENVIRONMENT

ALL SERVICES _____

TRANSFER OF COMMUNICATION_____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ)_____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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6   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING PILOT MESSAGE ACKNOWLEDGEMENT
 AND CONTROLLER NOTIFICATION OF MESSAGE STATUS

ALL SERVICES_____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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7   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING HANDLING OF FAILED MESSAGES

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

****
8   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING WORDING/PHRASEOLOGY USED IN
 DATA LINK MESSAGES

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

****
9   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING TIMING/PACING OF COMMUNICATIONS
 IN A FULL DATA LINK EQUIPAGE ENVIRONMENT

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

****
10   OPERATIONAL PROCEDURES (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING TIMING/PACING OF COMMUNICATIONS
 IN A MIXED EQUIPAGE ENVIRONMENT

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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***********************************************************
11            OPERATIONAL PROCEDURES (CONTINUED)
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*COMMENTS/RESERVATIONS CONCERNING COMPATIBILITY OF DATA LINK
 AND VOICE PROCEDURES

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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***********************************************************
12            OPERATIONAL PROCEDURES (CONCLUDED)
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*COMMENTS/RESERVATIONS CONCERNING (TESTBED) DESIGN FEATURES AND
 PRACTICAL USE OF DATA LINK ATC SERVICES

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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***********************************************************
13                      DISPLAYS
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*COMMENTS/RESERVATIONS CONCERNING DISPLAY OF DATA LINK EQUIPAGE
 AND ELIGIBILITY

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***********************************************************
14                   DISPLAYS (CONTINUED)
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*COMMENTS/RESERVATIONS CONCERNING DISPLAY OF DATA LINK MESSAGE AND
 TRANSACTION STATUS INFORMATION

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

****
15   DISPLAYS (CONCLUDED)

*COMMENTS/RESERVATIONS CONCERNING DISPLAY OF PRE-BUILT MENU
 MESSAGES

****
16   INPUTS/CONTROLS

*COMMENTS/RESERVATIONS CONCERNING MESSAGE ELIGIBILITY AND MESSAGE
 COMPOSITION RULES

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

****
17   INPUTS/CONTROLS (CONTINUED)

*COMMENTS/RESERVATIONS CONCERNING CAPABILITIES AND COMMANDS TO
 INITIATE UPLINK OF MESSAGE

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

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*********************************************************************
18                    INPUTS/CONTROLS (CONCLUDED)
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*COMMENTS/RESERVATIONS CONCERNING AUTOMATIC DELETION OF WILCO
 STATUS AND UPDATE OF NAS (DATA BLOCKS AND/OR DATA BASE)

ALL SERVICES _____

TRANSFER OF COMMUNICATION _____

ALTITUDE ASSIGNMENT (QZ) _____

INTERIM ALTITUDE ASSIGNMENT (QQ) _____

INTERIM ALTITUDE ASSIGNMENT (MENU) _____

APPENDIX E

WRAP-UP QUESTIONNAIRE RESULTS

TABLE OF CONTENTS

DESCRIPTION

This report documents the statistical treatment and results of the Wrap-Up Questionnaire which was given to the seven test controllers during the debriefing after the final test runs. A copy of the questionnaire is attached herein.

The questionnaire is comprised mainly of 7-level rating scales and free narrative comment questions. The numerical values and verbal labels attached to the 7-level rating scale questions are:

        7 = Very Good
        6 = Good
        5 = Slightly Good
        4 = Fair (center scale)
        3 = Slightly Poor
        2 = Poor
        1 = Very Poor

These values are used for the computation of the rating scale statistical results. Narrative comments for all questions are compiled and attached herein. Also, a frequency count of controllers making similar statements is attached.

RATING SCALE ANALYSIS

Table E-1 shows the resulting descriptive and inferential statistics for the 17 items rated using the 7-level rating scale. Means and variation about the means were computed for each of the items. Student's t scores were computed to test if the means were significantly higher or lower than center scale (4).

In table E-1 the items are presented in magnitude order of t score. A 5-percent confidence interval about each item mean was also computed. Notes at the bottom of the table give a brief explanation of the meaning of the table headings.

Comparing the t score to the center scale value of 4 indicates whether that mean rating is significantly above or below it. These ranks are given in the results below.

RATING SCALE DATA RESULTS

The following results, using a 95 percent probability criterion (p=.05) for significance, were obtained for the rating scale questions.

Of the 17 items rated, 12 were rated GOOD (significantly higher than FAIR), 5 were rated FAIR (did not differ significantly from FAIR) and none were rated POOR (significantly lower than FAIR).

TABLE E-1. OP EVAL WRAP-UP QUESTIONNAIRE RATING SCALE ANALYSIS ARRANGED
IN ORDER OF STATISTICAL SIGNIFICANCE

RATINGS FROM THE SUBJECTS   STATISTICAL RESULTS

1	2	3	4	5	6	7	N	MEAN	t.05	VAR	SDn-1	SE	RANGE		cs	thv	Shv	#	QUESTIONNAIRE ITEM
7	6	7	7	7	7	7	7	6.67	2.45	0.20	0.49	0.18	6.28	7.17	4	14.72	0.05	6c	QQ R FLID operability
6	6	6	6	7	7	5	7	6.14	2.45	0.41	0.69	0.26	6.15	6.78	4	8.22	0.05	6a	DL/OK FLID operability
7	5	6	6	7	7	6	7	6.29	2.45	0.49	0.76	0.29	5.59	6.98	4	8.00	0.05	6b	DL/OK S FLID operability
6	5	6	5	7	7	6	7	6.00	2.45	0.57	0.82	0.31	5.24	6.76	4	6.48	0.05	17b	R-D controller coordination
6	5	5	6	7	6	6	6	5.83	2.57	0.47	0.75	0.31	5.04	6.62	4	5.97	0.05	17e	Sector interphone coordination
6	5	6	6	7	4	6	7	5.71	2.45	0.78	0.95	0.36	4.83	6.59	4	4.77	0.05	17f	Pilot-Controller communication
5	6	6	6	7	6	7	7	5.86	2.45	0.98	1.07	0.40	4.87	6.85	4	4.60	0.05	17i	Overall efficiency (speed)
5	5	5	6	7	6	6	7	5.57	2.45	0.82	0.98	0.37	4.67	6.47	4	4.26	0.05	17j	Overall safety
6	4	6	6	7	5	7	6	5.83	2.57	1.14	1.17	0.48	4.61	7.06	4	3.84	0.05	17a	System capacity
7	4	6	6	6	4	4	7	5.29	2.45	1.35	1.25	0.47	4.13	6.45	4	2.71	0.05	8	Pilot response delays
5	3	6	6	7		7	6	5.67	2.57	1.89	1.51	0.61	4.09	7.25	4	2.71	0.05	17k	Overall workload
5	4	6	7	7	4		6	5.50	2.57	1.58	1.38	0.56	4.05	6.95	4	2.67	0.05	6d	QQ 2 ddd FLID operability
4	4			6	5	6	5	5.00	2.78	0.80	1.00	0.45	3.76	6.24	4	2.24	NA	17q	Aircraft conflicts
4	4		5	6	4	5	5	4.60	2.78	0.64	0.89	0.40	3.49	5.71	4	1.50	NA	17h	Flight strip handling
4	3	5	7	7	3	6	7	4.86	2.45	2.12	1.57	0.59	3.40	6.31	4	1.44	NA	17b	Keeping the picture
7	6		1	7	2	6	6	4.83	2.57	5.81	2.64	1.08	2.06	7.60	4	0.77	NA	17c	Weather handling
6	2	3	3	6	5	5	7	4.29	2.45	2.20	1.60	0.61	2.83	5.77	4	0.47	NA	1	Simulation realism

TABLE E-1. OP EVAL WRAP-UP QUESTIONNAIRE RATING SCALE ANALYSIS ARRANGED
IN ORDER OF STATISTIC, SIGNIFICANCE (Cont'd)

NOTES:

N   = Number of controllers responding to the questionnaire item.

MEAN   = The average item rating across all the responding controllers. General
           meanings of scale values are: 1 = VERY POOR, 4 = FAIR, 7 = VERY GOOD.

t.05   = Five percent significant t score levels with degrees of freedom = N-1.

VAR   = Variance of the controllers ratings about the item's MEAN rating.

SDn-1   = Corrected standard deviation computed from the variance.

SE   = Standard Error of the MEAN; expected variability about the MEAN if the
           study was repeated several times under the same conditions.

RANGE .05 = Five percent confidence interval centered about the MEAN within which,
            if the study was repeated several times, the new means should fall
            95 percent of the time.

RANGE .05
left column = Low limit of the range. Any lower value is significantly below the MEAN.

RANGE .05
right column = High end of the range. Any higher value is significantly above the MEAN.

thv   = Two-tailed Student's t tests to determine whether the MEAN deviates
           significantly from (falls above or below) a criterion value.

cs   = Center Scale (FAIR = 4.0).

shv   = Significance levels (p (.05) for the items' t scores. 05 = "better than"
           the criterion value, =.05 = "worse than" the criterion value,
           NA - Not significantly different from the criterion value.

Considering the nature of the questionnaire items, this shows a high acceptance of the Data Link concepts evaluated.

Rank ordering the t scores makes it possible to determine which items are notable as far as degree of preference.

QUESTION-BY-QUESTION RESULTS

Question 1 asks for a rating of the simulation realism. The resultant rating is FAIR.

Question 2 asks suggested improvements for realism. Twelve suggestions are made. See Narrative Comments section.

Question 3 asks if training is sufficient. The response is unanimous, 7 yes and 0 no. Significant.

Question 4 asks if the services were used often enough to give a fair evaluation. The answer was significantly yes for each.

		Yes	No
1.	Assigned Altitude ("S")	7	0
2.	Interim Altitude ("S")	7	0
3.	Interim Altitude Menu Text	7	0
4.	Transfer of Communication	7	0
5.	Free text	6	0

Question 5 asks to document any system malfunctions. Two are mentioned. See Narrative Comments section.

Question 6a asks to evaluate the data input, DL /OK ID. Controllers said unanimously (7-0) that it is needed, and works SIGNIFICANTLY GOOD.

Question 6b asks to evaluate the Data Link input, DL /OK S ID. Controllers said unanimously (7-0) that it is needed, and works SIGNIFICANTLY GOOD.

Question 6c asks to evaluate the Data Link input, QQ R ID. Controllers said unanimously (7-0) that it is needed, and works SIGNIFICANTLY GOOD.

Question 6d asks to evaluate the Data Link input, QQ Z ddd ID. Controllers voted 5 yes, 1 no, and 1 can't tell. It was rated SIGNIFICANTLY GOOD as to how it works, but a change is suggested to eliminate the ddd as unnecessary.

Question 7 asks about attention alarms. See the Narrative Comments section.

Question 8 asks to rate the pilot response delays. The controller ratings were SIGNIFICANTLY GOOD.

Question 9 asks if the extended pilot response delays of the supplemental run were noticeably longer. Yes=2, No=5.

Question 10 asks if Data Link could be used even with extended pilot delay. Yes=6, No=0, Can't Tell=1. This is significant.

Question 11 asks if the PVD were preferred displayed or suppressed. Displayed=6, Suppressed=1.

Question 12 asks what control events are best for free text. See the Narrative Comments section.

Question 13 asks for foreseen problems for aircraft transitioning in and out of DL coverage sectors. See Narrative Comments section.

Question 14 asks if the controller should have the capability to modify the Interim Altitude menu text. Yes=5, No=1, Can't Tell=1.

Question 15 asks if there is a need to string messages together for one send. Yes=4, No=2.

Question 16 asks how best to design menu text.
     Separate menus per service = 1
     One menu allowing stringing = 3
     A separate free text menu   = 2

Question 17 asks the projected effect of Data Link on 11 items. Seven items were rated significantly GOOD, four FAIR, and none SIGNIFICANTLY POOR. See table E-1 for items 17a to 17k.

Question 18 asks if during a handoff the receiving controller should also see the transfer of comm. up arrow. Yes=6, No=0, Can't Tell=1. Significantly approved.

Question 19 asks if Data Link is effective when things get busy. Three said more effective, one said less effective, one said equally, and two can't determine.

Question 20 asks if the pilot need check in by voice on the new frequency with Data Link. Yes=1, No=5, Can't Tell=1.

Question 21 asks if individual transfer of comm. messages can be selected as automatic such that the change frequency message is uplinked upon handoff acceptance. Yes=5, No=1, Can't Tell=1.

Question 22 asks for gaps in the system. See Narrative Comments section.

Question 23 asks what's liked best.   See Narrative Comments section.

Question 24 asks what's liked least.   See Narrative Comments section.

Question 25 asks what future services should Data Link do.   See Narrative Comments section.

At the end of the data runs for scenarios 1 and 2, controllers were asked to rate the traffic size per scenario on a scale from 1 to 10. This form is attached with the Wrap-Up Questionnaire. Also asked was the projected traffic rating which would require D side assistance. The results are below.

	Traffic size		Need D side	
	Avg	Range	Avg	Range
Scenario 1	4	2-6	5.4	4-6
Scenario 2	4.25	1-6	5.4	4-6

Interestingly, the controllers rated the traffic size as light-to-moderate (4) for both scenarios, yet rated the level where a D side should assist at 5.5 (moderate-to-heavy), only 1.5 points higher. Since all the controllers projected the need for a D side at 6, it's assumed that 5 (moderate traffic) is full capacity for one person at the sector. Thus, these ratings reflect traffic size in terms of a two-controller operation in the field, and not traffic size for the controller himself/herself in the simulation.

NARRATIVE COMMENTS

The complete compilation of narrative comments to the Wrap-Up Questionnaire is attached to this appendix. The comments that might be interpreted as a consensus are summarized below.

REALISM. Several items were mentioned that could increase realism: the inclusion of flight strips, increased and more varied traffic patterns, VOR's, radials, airways, more typical speeds, and turns.

ATTENTION ALARMS. Four controllers said no need for aural alarms. Three said FAILS should blink in full data block; two suggested something else would be better because blink is too similar to CONFLICT ALERT.

RESPONSE DELAY. Four responded that they became accustomed to the delay since they would only use Data Link for messages where the delay would not be a problem.

MULTIMESSAGE.   Four commented that the capability to string messages together for one send would be good if it does not introduce entry errors.

AUTO TOC. Four commented that an option to make transfer of communication automatic on an individual aircraft basis was a good idea.

GAPS IN THE SYSTEM. Five commented on envisioned "gaps" in the system, each one of which was different.

SUMMARY OF RESULTS

The seven en route controllers reported that the Data Link Op Eval had fair realism, training was adequate, and malfunctions minimal. They judged that they had sufficient use of the Data Link services to give a fair evaluation. Response delays indigenous do Data Link transmission were judged no problem.

New system entries, "DL /OK ID," "DL /OK S ID, "QQ R ID," and "QQ Z ddd ID" were judged significantly good, with a change recommended for Z to eliminate ddd. Menu text should have the capability of linking and modifying messages. No aural alarms were considered necessary for attention alarms. The most prevalent philosophy on alarms for failures was to blink it.

The projected effects of using the Data Link for ATC in the field were, for the most part, SIGNIFICANTLY GOOD. Four of the 12 effects were rated FAIR, and 8 were rated SIGNIFICANTLY GOOD including: system capacity, overall safety, efficiency, and controller workload. Good effects were also projected for sector interphone, R and D controller coordination, and pilot/controller communications.

Of the narrative answers in the comment section, the responses amounted to a majority for four questions;

1. Realism can be improved for the simulation.
2. No aural alarms.
3. Response delay is acceptable.
4. Multimessaging is good menu text item.
5. Auto TOC is a good feature.

Many ideas of future services are listed. A listing of narrative comments per question in the Wrap-Up Questionnaire follows.

E-7

NARRATIVE RESPONSES TO EACH QUESTION
WRAP-UP QUESTIONNAIRE

QUESTION 1.   No comments

QUESTION 2.   How can we enhance realism?

CONTROLLER

1   The design of the simulation is as good as it could be considering the limitation of the lab environment.

2   Maybe use an Aeronautical Center sector setup. Handoff the planes to us vs. their appearance. Allow the remotes to have quicker access of assigned altitudes.

3   More aircraft.

4   Vary the traffic patterns a little more, use better trained pilots.

5   Aircraft realistically would turn slower, pilots would read back full clearances and answer up quicker.

6   Have the Mode C work on all aircraft, don't have the aircraft "appear" so close to the traffic. Have flight process strips.

7   The lack of VOR's, radials, airways in UDS Center did have a limiting effect on realism. Also, speeds of 190-240 kt on jets is unrealistic. SIMOP's should be briefed on realistic speeds and begin the simulations accordingly.

QUESTION 3.   Any ideas as to other training that would have aided you?

CONTROLLER

7   I felt I needed a more complete briefing on procedures and potential of both the GAT and the NASA/AMES simulator.

QUESTION 4.   Did you use the services in this test often enough to be able to give a fair evaluation?

CONTROLLER

5   Good services.

QUESTION 4 (Continued)

CONTROLLER

7   I feel F/T needs additional development. Most types of
     F/T messages will probably be composed and delivered by
     D-side.

QUESTION 5.   Please document any inadvertent malfunctions that,
                working properly, would have helped you make a
                fairer evaluation.

CONTROLLER

1   The D/L functions worked consistently enough.

2   Lack of Mode C in scenario 1 made it too busy to try to
     evaluate (until we simply manually reported the altitudes
     w/o asking remotes).

4   None.

6   The items listed in #2.

7   None.

QUESTION 6a.   Please evaluate the following Data Link inputs:
                "DL /OK ID," Controller with track control
                establishes DL comm. with a/c (a/c is already on
                frequency).

CONTROLLER

1   Works good but procedures (like for track control) would
     be needed to prevent someone inadvertently using this.

7   But still requires manual coordination with transferring
     controller.

QUESTION 6b.   Please evaluate the following data link inputs:
                "DL /OK S ID," controller with track control
                establishes DL comm. and sends his frequency to a/c.

CONTROLLER

1   Better than DL /OK ID because it also sends the freq.

2   Must define procedure because I don't want somebody
     taking communications of a/c I might need to talk to.

7   Still requires manual coordination with transferring
     controller.

QUESTION   6c.   Please evaluate the following data link inputs:
                   "QQ R ID," controller with track control and DL
                   comm. uplinks the requested altitude to the a/c.
CONTROLLER

    1   Real good, because it minimizes number of keys to push.

    7   Very useful service for high altitude controller.

QUESTION   6d.   Please evaluate the following data link inputs:
                   "QQ Z ddd ID," initiating controller send the same
                   Int. Alt. to the pilot that the receiving controller
                   has already entered in the FDB.

CONTROLLER

    1   Don't know if this is necessary or if procedures can be
            written around it.

    2   I sent an incorrect altitude to aircraft (intentionally).
            After the initial acceptance by the a/c, there was no
            indication that this a/c received and is climbing to the
            wrong altitude.

    3   Specific sites only.

    7   This procedure is not routinely used in many facilities,
            however, _after the proper coordination_ it can still be
            a useful procedures.

QUESTION   7.   How were the attention alarms? Should anything be
                   made to blink or not blink? How about aural alarms?

CONTROLLER

    1   No aural alarms needed. Fail in data block is good
            enough.

    2   No aural alarms. An overambitious conflict alert in the
            facility is already making us complacent to blinking.
            Maybe a character in the altitude field indicating a need
            for action would be sufficient.

    3   No aural alarms.

    4   OK, but the fail on an altitude should flash, and an
            unsuccessful transfer of communication should flash in
            hour glass. There should also be a distinction between
            FAIL and when a pilot hits the UNABLE button.

QUESTION 7 (Continued)

CONTROLLER

5   No blinking. Blinking reminds a controller of conflict
     alert warning. No aural alarms. There is enough noise
     already in the control room.

6   If something fails I think the entire data block should
     blink to make you more aware of the failure.

7   In TOC, I feel the receiving controller needs an
     attention device when hourglass is displayed. Perhaps
     either highlight (double intensity) or perhaps even flash
     the hour glass for a few seconds parameter. Without the
     attention device, I found my normal scan being
     interrupted to check for eligibility.

QUESTION 8. How do you rate the pilot response delays?

CONTROLLER

1   If something immediate is needed to be done, voice will
     have to be used anyway, so even though there is delays
     it isn't a real major problem.

2   I got accustomed to it.

5   Data Link delays were good. Voice delays were not
     realistic, they took too long.

7   The response time was not significantly different than
     what we see today and did not cause a problem. However,
     I believe this is a critical issue that must be
     successfully resolved in system architecture prior to
     implementation. Response times greater than 12-20
     seconds would, in my judgement, be excessive for some ATC
     SERVICES in certain time-critical situations. Or,
     perhaps voice will continue to be the choice of
     controllers in those situations.

QUESTION 9. For the run with extended pilot response delay, were
              the delays noticeably longer?

CONTROLLER

1   Extended delays were not any worse since there's a delay
     with D/L anyway.

2   Unless the delays become unreasonable I don't think
     they're too difficult to compensate for.

E-11

QUESTION 9 (Continued)

CONTROLLER

5   The longer delays would not be helpful when busy.

7   Only in two or three instances did I notice a significant difference.

QUESTION 10.   Could Data Link still be utilized effectively even with the extended pilot response delay?

CONTROLLER

1   It would still work good for transfer of communication and most altitude changes.

2   See 9.

5   Only usable with transfer of communication; for altitudes changes, the delay is too long.

7   As it was experienced in the lab - yes, but see question 8.

QUESTION 11.   Did you prefer the PVD status list displayed or suppressed?

CONTROLLER

1   Don't need it if status shows up in data block in some form. The list takes too much time to look through.

2   I rarely used it anyway.

4   Needed for free text messages.

5   I could see responses to my messages at a glance.

7   I believe the status list is essential and should be displayed. However, it continues to need refinement to make it an effective tool. First, I feel it is not necessary to display "SENT" and "HOLD" on the receiving controller PVD during a TOC. Secondly, we need to continue to explore ways to "display the exception," i.e., failures, rather than display every "SENT." Also, my thinking at this time is that FT will become primarily a D-side function, therefore, display FT acknowledge in D-side RVD. In short, keep the STATUS LIST - but edit it substantially to keep in USABLE by the controller.

QUESTION 12.   What control events do you foresee would be best handled by free text?

CONTROLLER

1   Only during emergencies or when freq. ties are lost. I don't like it for control functions.

2   Local ride reports, miscellaneous messages.

3   Route changes.

4   Vectoring and speed adjustments minor route amendment.

5   Send messages from company or ARINC, send WX sequences, etc.

6   A freq. change during stuck mick times.

7   (1) Field 10 amendments, that is, _route revisions._ (2) Current ride reports when not included in weather products. (3) Speed assignments. (4) Very limited use as a radar vector tool. Generally speaking, I found FT to be marginally useful to the "R" controller during slow periods, and not at all useful during busy periods. The "R" controller simply does not have the time to make large numbers of KEYSTROKES.

QUESTION 13.   What kind of problems are foreseen when aircraft transition in and out of DL coverage sectors?

CONTROLLER

1   Controllers transitioning between use of D/L and freq. It might cause some confusion unless the areas of lack of coverage were well known.

2   As long as DL eligibility can be /OK'd, none at all.

3   This should not be a problem. Either the controller does or does not have Data Link.

4   Lost aircraft communication, if only temporary causing the DL controller having to enter extra messages or make additional voice transmission.

5   Can't envision any right now.

6   The pilot attention is the weak link and/or the placement of the Data Link device.

QUESTION 13 (Continued)

CONTROLLER

7 It is difficult to answer this question without more information about the coverage capability of the Mode S sensors. However, it is a crucial question that will need to continue to be looked at.

QUESTION 14. Should the controller have the capability to modify the interim altitude menu text?

CONTROLLER

1 They should be set by facility procedure if an individual controller has different preferences he can always do it another way.

2 Give us the chance to issue the particular clearances we like to use.

4 Not really important because the controller will know which items he will be using and probably won't have it displayed. Also, I suggest that the menu text and the status list be put on different keys.

5 Different controllers have different restrictions that they use, they should have the ability to use the restrictions that they want.

7 In other words, modify DDD to 120, 230, etc. However, I foresee most menu text items to be predetermined by sector and specified by Procedures Facility Directives.

QUESTION 15. Is there need to string messages together with one send (i.e., (1) fix cross alt. (2) speed, (3) heading = DL 1 2 3 FLID enter)?

CONTROLLER

1 That would save a lot of time for both pilot and controller as long as the individual items were clearly identified in a format the pilot would notice.

2 I believe tnat one clearance per transmission sets a better rhythm and reduces chances of pilot error.

4 Absolutely.

5 During an arrival sequence, these three items are given together frequently.

QUESTION 15 (Continued)

CONTROLLER

7   The need is there, and it should be available as a
controller tool just as it is today. Naturally, it will
be applied only in carefully controlled areas.

QUESTION 16.   How best to design menu text?
Separate menus (AA, IA, speeds, headings, free
text)? One menu for string Xing, IA speeds,
headings¿? A free text menu (of typical free text
messages)?

CONTROLLER

1   One menu for multiple messages is needed.

2   Try some different ways.

4   Stringing is an excellent idea.

5   Need to be able to put in whatever restrictions are
needed, within a defined order. Sometimes IA, speeds may
need to be sent without headings, other times all three
need to be sent.

7   I continue to believe it will be a very valuable tool for
the controller; however, substantial design work remains
to be done to maximize its utility to the controller.
Some of this may be facility or even sector specific.
One principle that should be further incorporated in it
is to minimize the possibility of inadvertently selecting
the wrong MT message. Instead of naming them simple A-
Z, perhaps identify the message by a Letter/Number/Name
that actually bears a resemblance to the message. As far
as stringing together vs. individual menus, I feel we
need to look at those options in a test bed situation
before I can make an informed judgment. Also, given the
increased capacity of ISSS over the PVD, the answer would
be different.

QUESTION 17.   For the Data Link Services tested, what would be the
projected effect of Data Link at your position on
the following:

CONTROLLER

1   Safety _may_ increase due to reduced workload.

QUESTION 17 (Continued)

CONTROLLER

2   I found that when I was issuing verbal clearances my mouth was busy, and when I was issuing D/L clearances my hands were very busy.

4   On frequency changes.

5   When using Data Link mostly and not much talking it tended to lull me into a relaxed mode that lowered my attention level.

7   At this stage I would have to qualify most answers with "It depends."

QUESTION 18.   During a handoff, should the receiving controller also see the up arrow in the FDB when a TOC is sent to the pilot?

CONTROLLER

1   Not a need to know, but extremely helpful.

QUESTION 19.   When things get busy is Data Link
More effective
Less effective
Equally effective
Can't determine?

CONTROLLER

1   Only if a D-side or coordinator is involved. With only one person working it isn't anymore effective because you still have to do everything.

2   With more practice I think I (or two people working a sector) could issue two clearances simultaneously.

5   Especially helpful is transfer of communications function.

6   My answer may change if these task could be done by your D-side, but we did not get to experience test.

7   In the test environment - I found that at 20% equipage and busy session I did not use Data Link. At 80%, it was feasible to use it more. However, some of the controller workload may be shared with D- and/or H/O controller through proper procedures.

QUESTION 20.   Since the pilot has the new frequency on display for reference, does he need to voice check in on the new frequency?

CONTROLLER

1   Even if he doesn't come over, with D/L you can always go get him again.

2   As long as he is receiving the correct info.

4   But there needs to be some way of <u>insuring</u> that he switches to the correct freq.

5   But we need to make sure that pilots switch over when given a new frequency, maybe the Data Link could be tied into the pilots actually switching the numbers on their radio.

6   I personally like the verbal enforcement.

7   I feel that during field implementation, a voice check is still desirable.

QUESTION 21.   Is there a need for selectable automatic TOC (i.e., change frequency message is uplinked when receiving controller accepts handoff) on a per aircraft basis? Possible entry could be adding "S" to handoff initiation.

CONTROLLER

1   That could be useful in some sectors.

2   Anything to save an entry - make indication in data block.

4   Excellent idea.

5   That would be helpful as long as it is <u>only</u> on a per aircraft basis, many times aircraft are handed off prior to the time that they should be shipped.

QUESTION 22.   Using Data Link should leave no "gaps" in the system. Did you see any places where gaps in positive control could occur? If so, any ideas as how to prevent them?

CONTROLLER

1   Holes in coverage if they are not well known could be a serious problem.

QUESTION 22 (Continued)

CONTROLLER

2   If the pilots cleared altitude is different than that reflected in the data block, then let's see it. (i.e., "280T263" Time Share sent altitude to show "290S263."

3   No. Positive control is maintained via radio.

4   Yes. When an interim altitude not sent to the pilot overrides the actual altitude sent previously that failed. A failed altitude should always have a flashing FAIL time share with the altitude that failed and maybe even the previous assigned altitude. Must remember that a failed altitude must still be protected for.

5   Even with Data Link, pilots can comply in a timely manner or not; their choice. I cannot envision how to correct this "gap."

6   No.

7   I believe a TOC without a voice check-in on the freq. does leave a gap during entire stages of implementation. I believe voice check-in is desirable.

QUESTION 23.   What about Data Link do you like best, and why?

CONTROLLER

1   If another person is doing some of the inputs, it leaves more time for the radar control to handle traffic situations.

2   The ability to transfer communications. The pilot being able to read the frequency greatly reduces the chances for listening errors often encountered when transferring communications.

3   It has the capability of increasing the number of aircraft that a given sector can control.

4   Don't know what I like best, but not having to deal with incorrect pilot readbacks has to be the biggest advantage.

5   I like the ability to send messages to pilots even if the frequencies go out, or there is a stuck mike or they are just not answering by voice. It would be a good backup so we can stay in contact almost 100% of the time.

QUESTION 23 (Continued)

CONTROLLER

6   I like the "ability" to use it when I decide. It is a
     tool that with experimentation each controller will
     determine what function he/she feels comfortable using.
     The stuck mike scenario Data Link would be a blessing.

7   a.   The ability to free-up voice channel by uplinking
     routine and repetitive clearances (and weather produces).
     b.   An   additional   backup/emergency   communications
     channel.
     c.   The potential to share more of workload to D-
     controller and/or Handoff Controller.

QUESTION 24.   What about Data Link do you like least, and why?

CONTROLLER

1   Possibility of coverage holes.

2   No readbacks and the lack of ability to double check
     assigned altitudes of transitioning aircraft - (Maybe
     they should check on while a/c in level flight remain
     silent).

3   It will take to long to implement.

4   The Hourglass symbology in front of the call sign has to
     go. It is too close to the first letter of other call
     sign   and   causes   confusion   between   our   carrier
     designations such as AL, XL, XAL, XEAL, XAAL.

5   In the future when a majority of the a/c have it and we
     are using it a lot, I think it will be more of a problem
     staying alert.

7   a.   During heavy traffic, the switching back and forth
     from voice to D/L makes it difficult to maintain the
     "rhythm" that is required to work heavy traffic.
     b.   Loss of "personal contact" with pilots.

QUESTION 25.   What future services would you like to see Data Link
                do?

CONTROLLER

1   Automatic altimeter uplinks (controller out of the loop,
     so he doesn't even have to think about the altimeters).
     Menu text multiple message uplinks (not in free text
     though) such as speed control, heading.

E-19

CONTROLLER

2   Assign headings - (i.e., QAK or DL H dd CID)(dd = Heading divided by 10), i.e., 34 = 340
     Assign speeds - (i.e., QAK or DL S dd CID) (dd=Airspeed divided by 10), i.e., 25 = 250
     Assign Routes - (i.e., Tie in the Data Link with my route QAK similar to the way you have done with the altitude. Expand the use of the route key to allow (a) entering a heading to intercept an airway, (b) the airways, (c) enter a previously defined route stored in a database. Link the Data Link with extended flight management database systems in the cockpit.

3   Weather and other messages that are workload on the controller and not specifically control related.

4   Provide for two-way communication with the pilot, allowing the pilot to send lengthy route change request would be a great advantage.

5   I would like to see NOTAMS, SIGMETS, center WX advisories, etc., issued via Data Link. I would like a capability to send these message and others composed via free text to all airplanes on my frequency with one message. I would like to be able to send routings up to aircraft via Data Link at the same time it is being updated in the computer. Maybe we could also find a way to issue holding instructions via Data Link. I think it would be easier for pilots to read long, and, complicated instructions than to hear them over, and over, and over sometimes on lousy frequencies.

6   Automatically transmit latest ATIS, SIGMETS, weather advisories. The menu text should be open for changes or additions by the controller at all times. As things in the sector change, i.e., if the menu text is pre-established or supervisor established and you would go into unforeseen holding you could not Data Link the holding instructions, which could really help and may be the difference between going under and not.

7   I believe the next step is to develop D/L products that can be used by G/A and other VFR pilots, such as exchange of traffic information, airspace information, D/L weather products.

ATTACHMENT

Name_____   Data Link Evaluation
                                             FAA Proj. No. T2001B
Date_____   Sector_____   4-18-89

WRAP-UP QUESTIONNAIRE

1. How would you rate the simulation realism? (Circle One)
Note: The abbreviations below will be used later on.
        Consider "F" as borderline (i.e., maybe) acceptable.

Very Good (VG)	Good (G)	Slightly Good (SG)	Fair (F)	Slightly Poor (SP)	Poor (P)	Very Poor (VP)	Can't Tell (CT)

2. How can we enhance realism? (Use extra space on back.)

_____

_____

_____

3. Was training sufficient? Yes___, No___. Any ideas as to other
training that would have aided you?

_____

_____

4. Did you use the services in this test often enough to be able
to give a fair evaluation? (Circle one, CT = can't tell)

1.	Assigned Altitude ("S")	yes	no	CT
2.	Interim Altitude ("S")	yes	no	CT
3.	Interim Altitude Menu Text	yes	no	CT
4.	Transfer of Communication	yes	no	CT
5.	Free Text	yes	no	CT

Comment?_____

_____

5. Please document any inadvertent malfunctions that, working properly, would have helped you make a fairer evaluation.

_____

_____

6. Please evaluate the following Data Link inputs especially encountered in the last run. Circle the rating.

a. DL /OK ID Controller with track control establishes DL comm. with a/c. (a/c is already on frequency.)

      Is this needed? yes____   no____   can't tell____

      How well does it work?   VG G SG F SP P VP   CT

Comment?_____

      _____

b. DL /OK S ID   Controller with track control establishes DL comm. and sends his frequency to a/c.

      Is this needed? yes_____   no_____ can't tell_____

      How well does it work?   VG G SG F SP P VP   CT

Comment?_____

      _____

c. QQ R ddd ID   Controller with track control and DL comm. uplinks the requested altitude to the a/c.

      Is this needed? yes____   no_____   can't tell_____

      How well does it work?   VG G SG F SP P VP   CT

Comment?_____

      _____

d. QQ Z ddd ID   Initiating controller sends the same Int. Alt. to the pilot that the receiving controller has already entered in the FDB.

      Is this needed? yes____   no_____   can't tell_____

      How well does it work?   VG G SG F SP P VP   CT

Comment?_____

_____

7.   How were the attention alarms?   Should anything be made to blink or not blink?   How about aural alarms?

_____

_____

8.   How do you rate the pilot response delays?   Disregard the second-to-last run (which had extended delays).

Circle one (see 1.):   VG   G   SG   F   SP   P   VP   CT

Comment?_____

_____

9.   For the second-to-last run (with extended pilot response delay), were the delays noticeably longer?   yes____   no____.

Comment?_____

_____

10.   Could Data Link still be utilized effectively even with the extended pilot response delay?   yes____   no____   can't tell____

Comment?_____

_____

11.   Did you prefer the PVD status list displayed or suppressed?
      (Check one)   Displayed_____   Suppressed_____

Comment?_____

_____

12.   What control events do you foresee would be best handled by free text?

_____

_____

13.   What kind of problems are foreseen when aircraft transition in and out of DL coverage sectors?

_____

_____

14.   Should the controller have the capability to modify the interim altitude menu text?   yes___   no___   can't tell____

Comment?_____

_____

15.   Is there need to string messages together with one send (i.e., (1)Fix cross alt, (2)speed, (3)heading = DL 1 2 3 FLID enter)?
                 yes____   no____   can't tell_____

Comment?_____

_____

16.   How best to design menu text?
      Separate menus (AA, IA, speeds, headings, free test)_____
      One menu for stringing Xing, IA, speeds, headings) _____
      A free text menu (of typical free text messages)   _____

Comment?_____

_____

17.   For the Data Link services tested, what would be the projected effect of Data Link at your position on the following:
(Check box, leave blank if cannot project.)

PROJECTED EFFECT ON	VG	G	SG	F	SP	P	VP
System capacity	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Keeping the picture	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Weather handling	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
R-D controller coordination	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Sector interphone coordination	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Pilot-controller communications	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
A/C conflicts (system errors)	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Flight strip marking/handling	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Overall efficiency (speed)	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Overall safety	I	I	I	I	I	I	I
	I	I	I	I	I	I	I
Overall controller workload	I	I	I	I	I	I	I
	I	I	I	I	I	I	I

Comments?_____

_____

18. During a handoff, should the receiving controller also see the up arrow in the FDB when a TOC is sent to the pilot?
         yes____,   no____,   can't determine____,

Comment?_____

_____

19. When things get busy is Data Link _____ more effective
                                       _____ less effective
                                       _____ equally effective
                                       _____ can't determine

Comment?_____

_____

20. Since the pilot has the new frequency on display for reference, does he need to voice check in on the new frequency?
         yes____, no____, can't tell_____

Comment?_____

_____

21. Is there a need for selectable automatic TOC (i.e., change frequency message is uplinked when receiving controller accepts handoff) on a per aircraft basis? Possible entry could be adding "S" to handoff initiation. yes____ no____ can't tell____

Comment?_____

_____

22. Using Data Link should leave no "gaps" in the system. Did you see any places where gaps in positive control could occur? If so, any ideas as how to prevent them?

_____

_____

_____

23. What about Data Link do you like best, and why?

_____

_____

_____

_____

24. What about Data Link do you like least, and why?

_____

_____

_____

25. What future services would you like to see Data Link do?

_____

_____

_____

_____

_____

_____

APPENDIX F

AIRBORNE TEST SCENARIOS

TABLE OF CONTENTS

The pilots flew two different scenarios at altitudes and speeds (maximum of 180 knots (kts) representative of general aviation aircraft operating under Instrument Flight Rules (IFR) conditions. The field elevation for the General Aviation Trainer (GAT) simulator, though not representative of the Atlantic City (ACY) - Philadelphia area, was set at 5,000 feet (ft) mean sea level (m.s.l.). This allowed the pilots to reach the assigned en route cruising altitudes (12,000 ft for scenario #1 and 11,000 ft for scenario #2) in an accelerated fashion. Before each run began, the subject pilots were issued a clearance delivery by the inflight observer and given instructions to make requests for weather (WX). In voice runs, pilots tuned to ACY Flight Service Station (FSS) for destination terminal WX and en route winds aloft. In data link runs, pilots were instructed to use the Teledyne display. Experimenters provided ground taxi instructions (to the departing runway,) tower, departure and approach controls.

SCENARIO #1.

GAT pilots flew a westbound route totaling 93 nautical miles (nmi) (see figure F-1). They departed at an initial heading of 270 and were cleared to 8,000 ft m.s.l. Before reaching the assigned altitude, departure handed off N8417P to Universal Data Set (UDS) Center. Shortly after inception into the simulation (control from UDS Center), the pilots were instructed to climb to the assigned altitude of 12,000 ft (or given an interim altitude of 10,000 ft, then the assigned altitude of 12,000 ft). After level off and before reaching the sector boundary, the inflight observer prompted the pilots to make a request for any pilot reports (PIREPS) in the area. In voice runs, since the GAT simulator had one radio, the pilots requested from UDS Center a change of frequency. The controller issued the instructions to "...report back up in 3 minutes." Similarly, after hand-off to the next controlling sector, the inflight observer prompted the pilots to make a request for a surface observation at the destination airport. On the final approach, UDS Center instructed the pilots to descend to 7000 ft m.s.l. (2000 ft above ground level (AGL) for a straight-in Instrument Landing System (ILS) approach to the destination airport. The controller issued a final command to contact approach control within 15-20 nmi from the airport. A total of four heading changes were made during this scenario.

LOW SECTOR 17 (FREQ 133.2)

START

VCN (CEDAR LAKE)
VOR 115.2

$\dfrac{270}{5}$

$\dfrac{251}{16}$

$\dfrac{249}{29}$

RHM (RHOME)
VOR 112.8

LOW SECTOR 03 (FREQ 133.0)

$\dfrac{238}{9}$

DQO (DUPONT)
ILS RWY 21
LOC 110.1
VOR 114.0

$\dfrac{207}{34}$
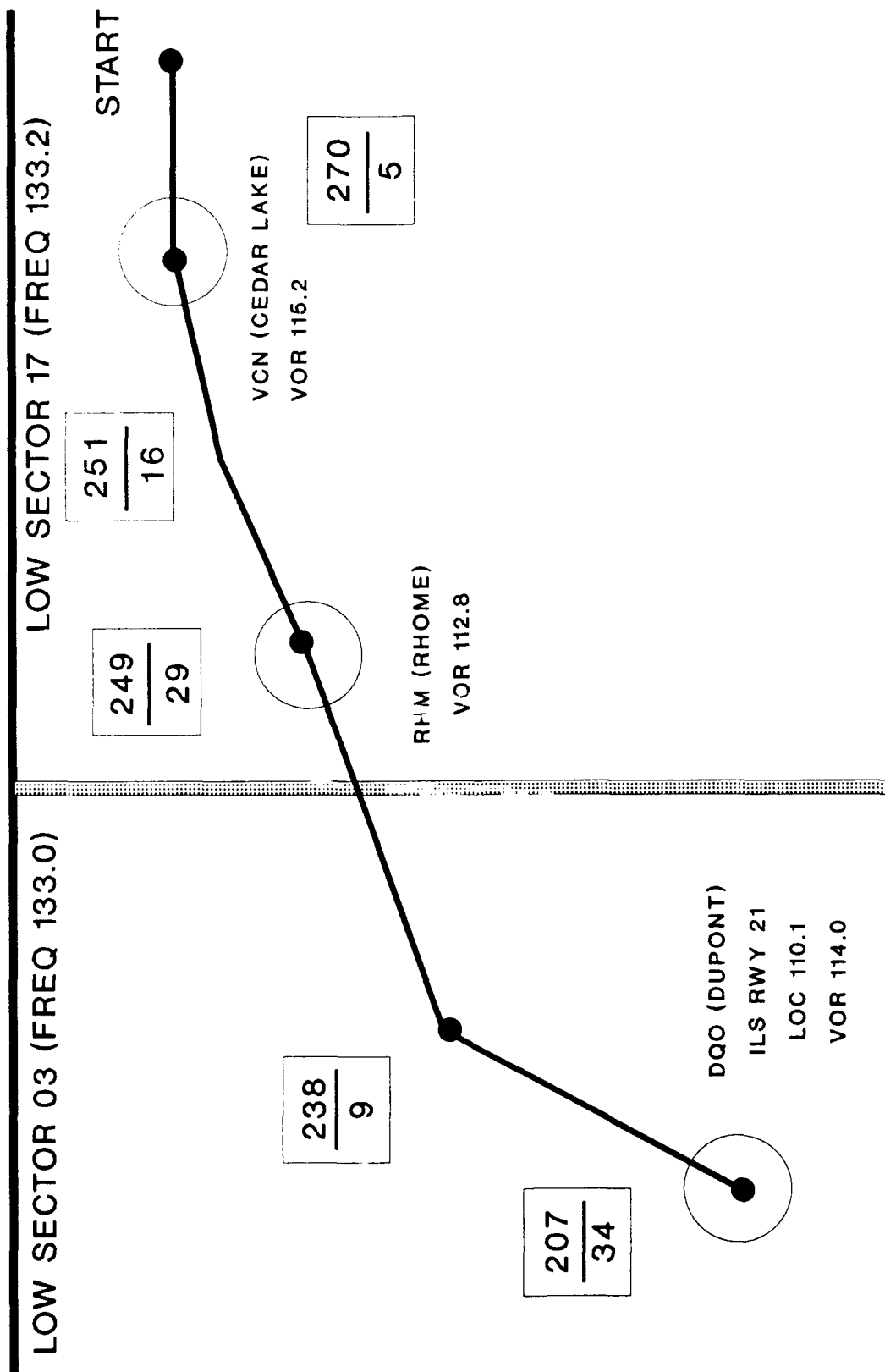
FIGURE F-1. GAT FLIGHT PLAN SCENARIO #1

SCENARIO #2.

The scenario was run in an easterly direction with one less heading change and an additional 5 nmi of flight (see figure F-2). The inflight observer, as in scenario #1, instructed the pilots to make two WX requests before release and two additional requests while inflight. The initial clearance altitude and heading were 9,000 ft and 090, respectively. Upon reaching 9,000 ft, the simulator appeared in the simulation. Air Traffic Control (ATC) instructions included two altitude assignments from 9,000 to 11,000 ft and from 11,000 to 7,000 ft. A frequency change (sector handoff) was issued midway in the flight. Total simulation time for each run was approximately 40 to 45 minutes with 10 minutes accounting for preflight check, clearance delivery, and ground/tower/ departure procedures as described earlier.

B-727 SCENARIOS

The B-727 flight plan followed an eastward route from Philadelphia to Atlantic City (see figure F-3). Along with EAL55, a number of other simulated aircraft flew the same route; 8 aircraft in scenario #1 and 11 aircraft in scenario #2. Special overflight routes were incorporated in the scenarios to produce potential conflicts. It was the nature of these conflicts and the presence of additional high altitude aircraft which caused variations in the amount and type of ATC instructions given to EAL55 in any one run. (The GAT received consistent amount of instructions across all runs.) Additionally, the number of individually controlled sectors along the route for EAL55 decreased from 3 to 1 for scenario #1 and scenario #2, respectively. This was due to the separation of the UDS Center airspace into two distinct environments; one representing a simulated departure airspace and the other a simulated approach airspace.

SCENARIO #1.

EAL55 was released into the simulation at 12,000 ft with an initial heading of 038. The initial airspeed and climb rate were 325 kts and 800 ft/min, respectively. The relatively low rate of climb was used so as to cause potential conflicts with the overflight routes (to create workload for the controllers). The scenario was 198 nmi in length and required nine heading changes. EAL55 started out in a low sector with instructions to climb to 23,000 ft. A frequency change from a low to high sector usually proceeded an assignment to 25,000 ft. The high sector controller, in turn, instructed EAL55 to fly

F-3

LOW SECTOR 17 (FREQ 133.2)

LOW SECTOR 03 (FREQ 133.0)

MIV (MILLVILLE)
ILS RWY 9
LOC 110.9
VOR 114.8

090 / 12

ENO (KENTON)
VOR 111.4

122 / 28

101 / 51

MXE (MODENA)
VOR 113.2

090 / 7

START
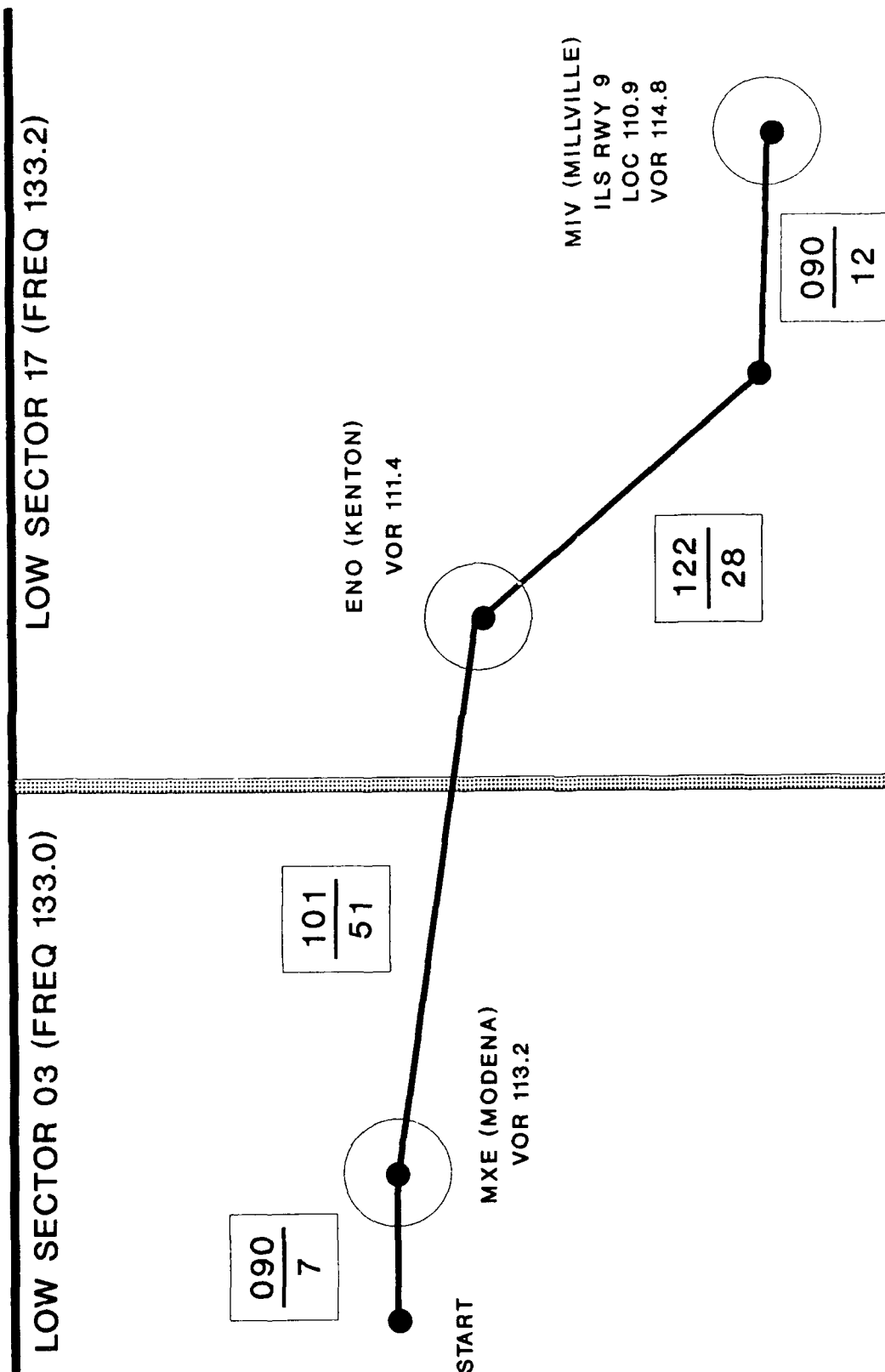
FIGURE F-2. GAT FLIGHT PLAN SCENARIO #2

Initial Point PHL
12,000 feet
325 IAS

Scenario 1 HDG 038
Scenario 2 HDG 068
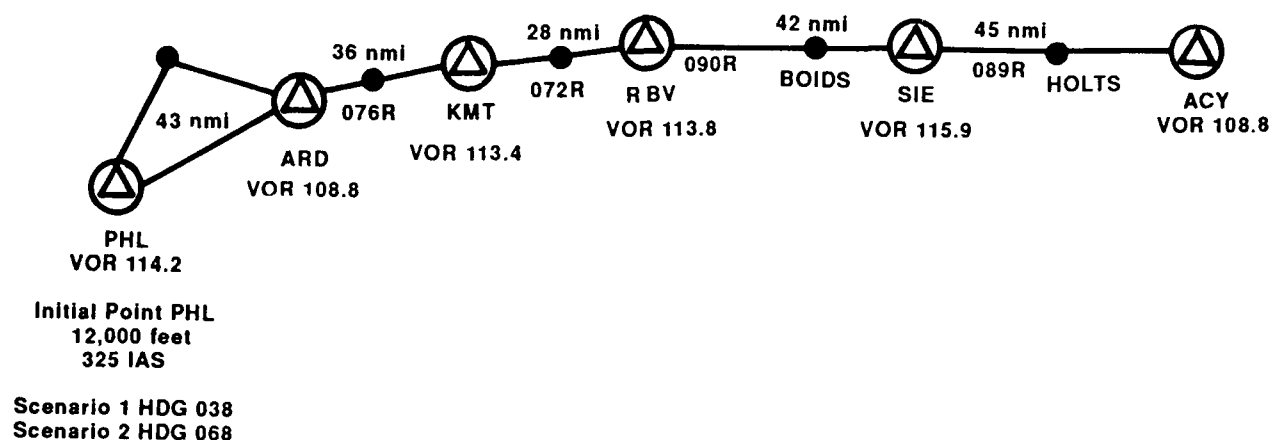
FIGURE F-3.   B-727 SCENARIOS

to 27,000 ft. After level off at the cruising altitude (maintained no longer than 5 minutes in any run), EAL55 received another frequency change to a high sector. The controller then issued an altitude assignment to 24,000 ft, followed by a frequency change to a low sector controller who, in turn, issued a final assignment of 12,000 ft.

SCENARIO #2.

EAL55 was released at 12,000 ft with an initial climb rate of 800 ft/min and an airspeed of 325 kts. Scenario #2 was the same as scenario #1 except for an initial heading of 068. Scenario #2 was 194 nmi in length and required eight heading changes. As noted by the initial low altitude (12,000 ft), EAL55 was part of the departure airspace. Because of the new sectorization, EAL55 was exposed to only one handoff (UDS Center low-to-high) which occurred midway in the flight. The departing sequence of ATC instructions paralleled those of scenario #1. After reaching an assigned altitude of 27,000 ft, the number of ATC instructions decreased and the type of instructions varied with each controller group. Though both scenarios represented medium to high traffic loads, scenario #2 represented an increased level of potential ATC conflicts.

To counteract the difference in number of frequency changes in each scenario, a simulated frequency change was issued prior to EAL55's release into scenario #2. This was accomplished by having the inflight observer instruct the first officer to touch "SELF TEST" on the Teledyne. Touching SELF TEST causes a "RUNNING" followed by "PASSED !" indication (refer to appendix G, figure G-7). Upon returning to MAIN the annunciation "TOUCH FOR ATC MESSAGE" was displayed which contained the simulated frequency change. This was an attempt to add to the workload to correct for the decrease (from scenario #1) in the number of controlled sectors in the flight plan.

APPENDIX G

COCKPIT DISPLAY/CONTROL SPECIFICATIONS

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TELEDYNE SPECIFICATIONS

The display device used was a Teledyne Interactive Display Unit (IDU), Model 2229346023, upon which had been programmed, text appropriate to the service being used. See figure G-1.

SPECIFICATIONS.

Type: Light emitting diodes (LED), 32 LED's/inch, 128 by 118 LED's

Interactive Characteristics: via 24 X & 21 Y axis infrared beams

Output: Standard ASCII character set Electrical Interface RS-232

The cockpit of the GAT and B-727 (with the Teledyne installed) can be seen in figures G-2 and G-3, respectively.

FORMAT CHARACTERISTICS

The opening or main menu format is shown in figure G-4. This menu allowed for selecting various weather products, messages received, and user system set up. A location identifier (LOCID) menu (figure G-5) allows the user to select a WX station of interest. In this design, a list of six LOCID's was presented; an on-screen keyboard option (figure G-6) was also available. The system set up menu (figure G-7) allowed various system parameters to be adjusted. Finally, on the main menu, a message list option (figure G-8) allowed retrieval/review of the eight most recent WX or ATC messages.

The package of services for this evaluation included two ATC and four weather services. An example of each service format is presented below along with a brief description. The example formats are representative of those seen by the GAT pilots during the evaluation. The B-727 formats, while similar, were slightly different to reflect the altitude environment difference. In addition to the two fixed ATC services, the subject controllers were able to create and send ATC oriented "free text" (20-character limit) messages, e.g., heading or speed changes.

WEATHER.

Terminal Forecast (FT) - A 24-hour prognosis of weather conditions within the immediate vicinity of a selected location; includes sky and ceiling, visibility, weather, obstructions to vision, cloud heights, and whether visual or instrument conditions are expected (see figure G-9).

Winds/Temperatures Aloft (FD) - A report of projected winds and temperatures for a range of altitudes; includes wind speed, wind direction, and temperature (see figure G-10).
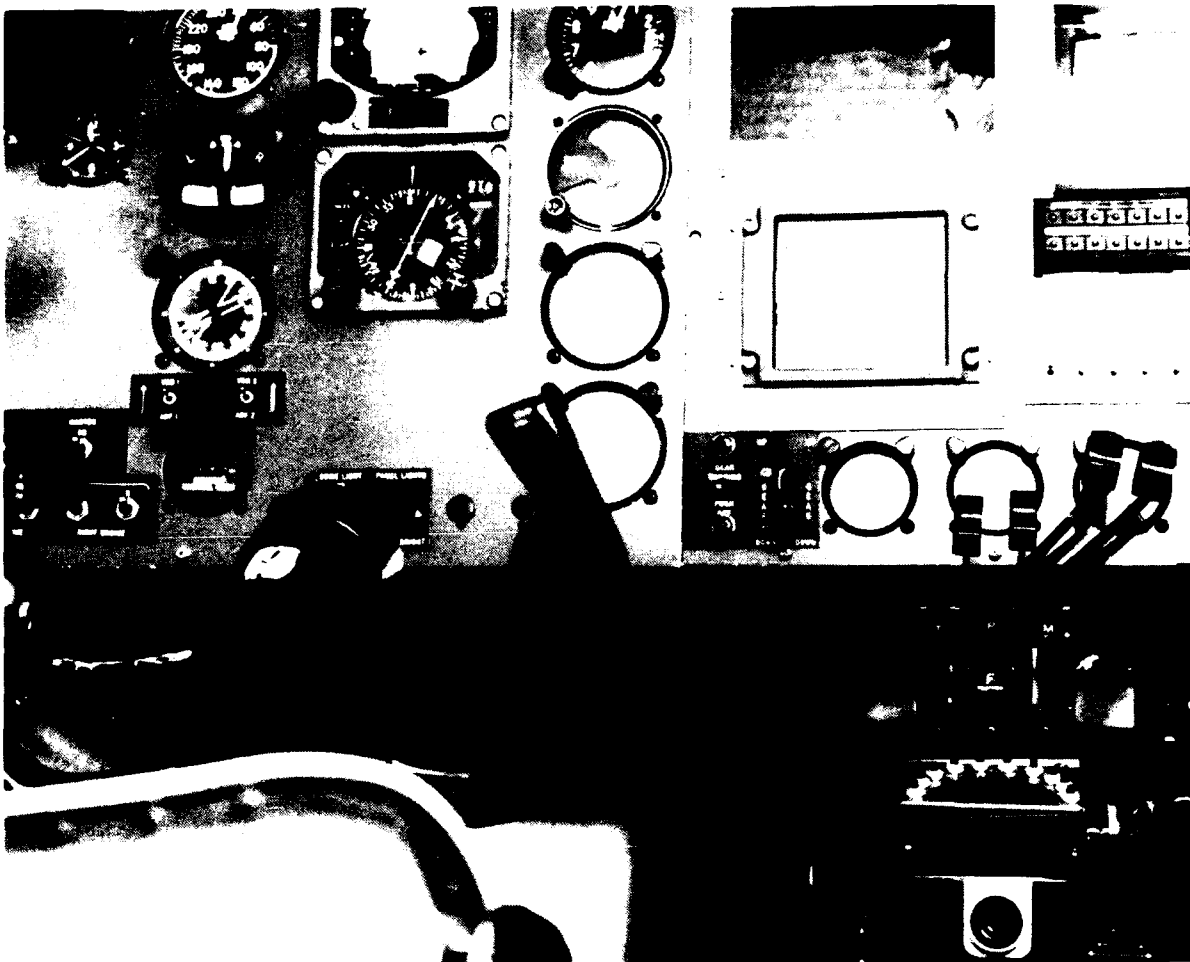
FIGURE G-1. TELEDYNE DISPLAY
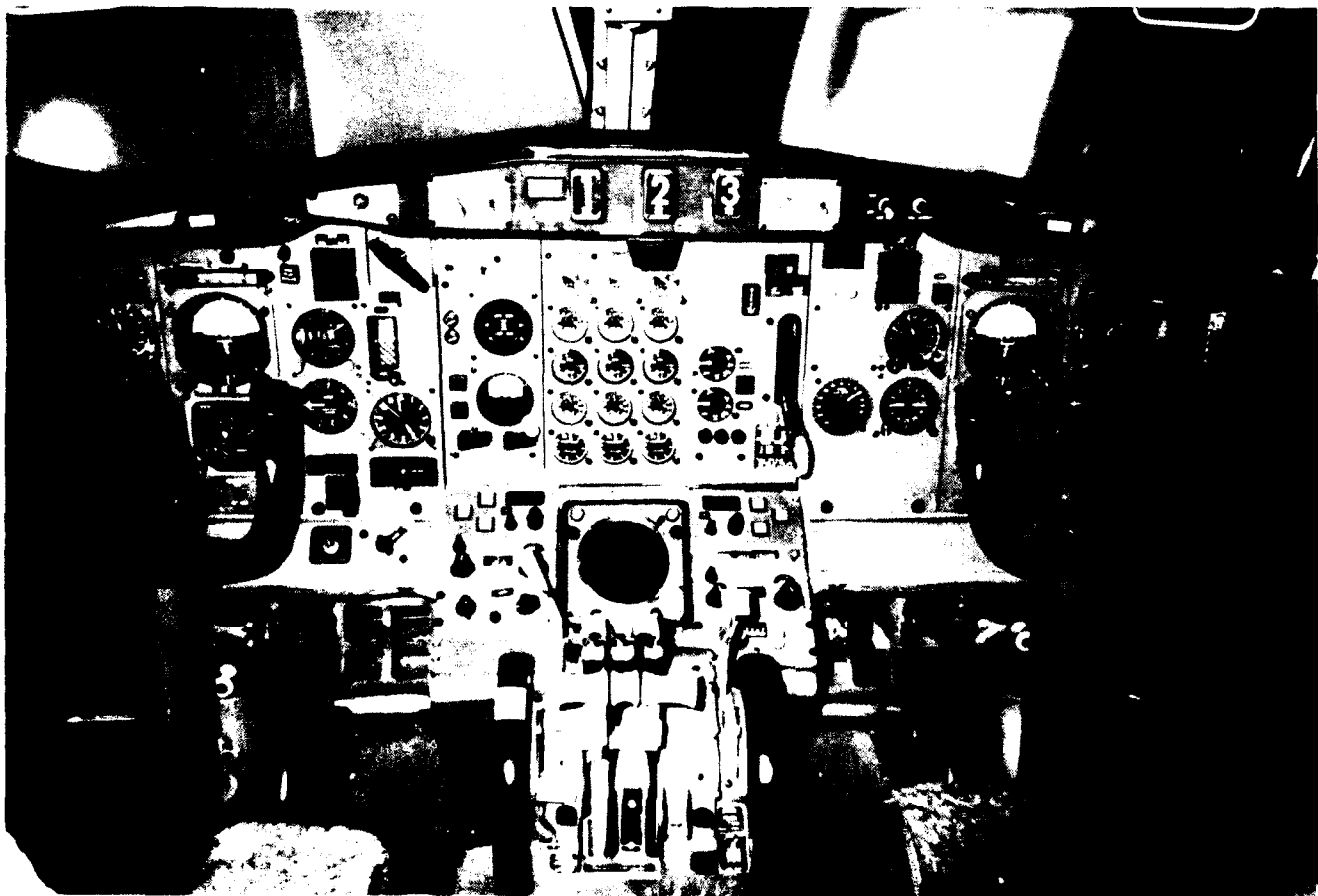
FIGURE G-2. B-727 COCKPIT
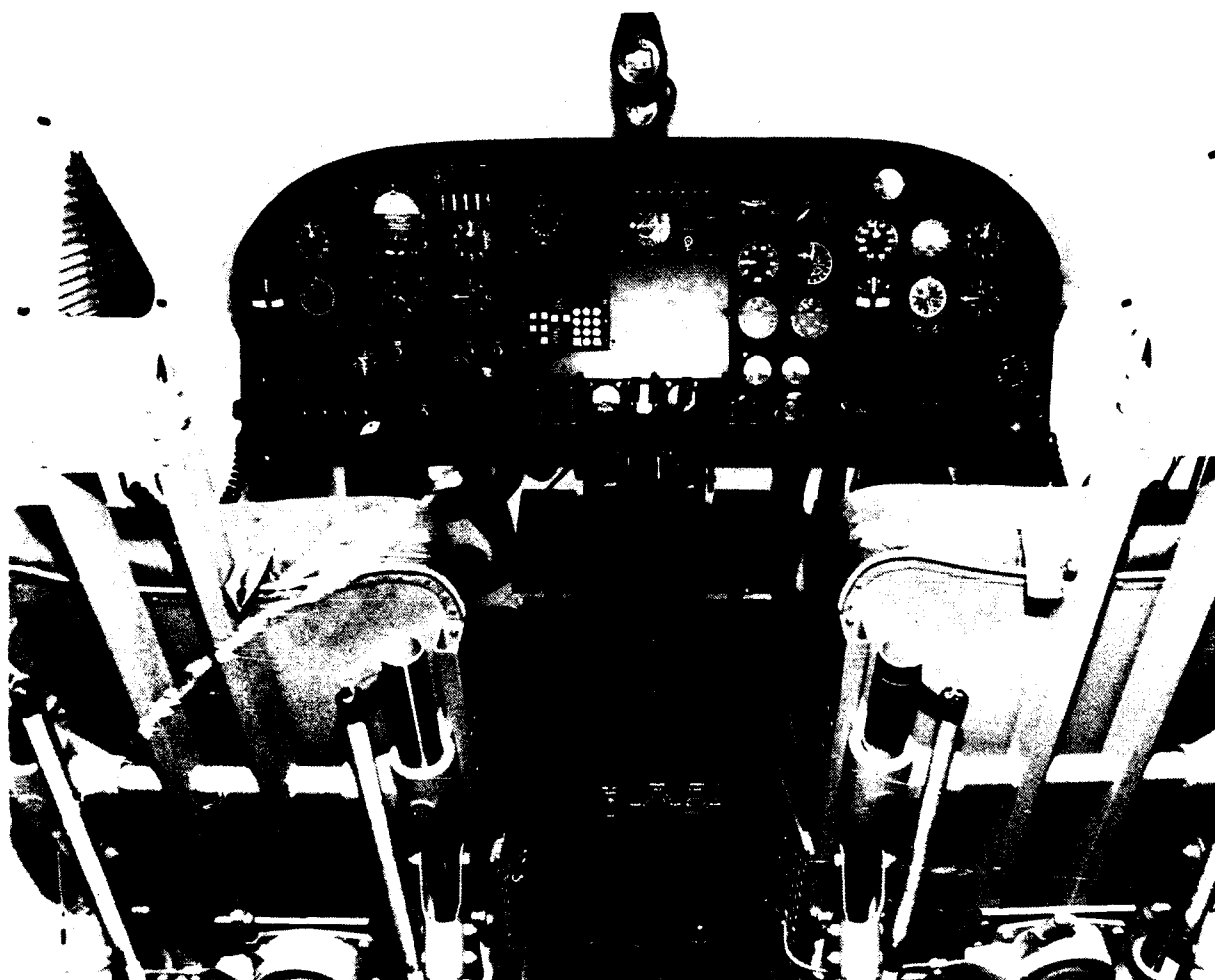
FIGURE G-3. GAT COCKPIT

```
┌─────────────────────────────┐
│ DATALINK MAIN MENU          │
│ → TERMINAL FCST             │
│ → SURFACE OBS               │
│ → WIND/TEMP                 │
│ → REQUEST PIREP             │
│                             │
│ → MESSAGE LIST              │
│ → USER SET UP               │
├─────────────────────────────┤
│                             │
│                             │
└─────────────────────────────┘
```

FIGURE G-4.   THE MAIN MENU

```
┌─────────────────────────────┐
│        LOCATION LIST        │
│                             │
│   TERM FCST FOR:     ENO    │
│                             │
│ → ACY   → DQO  → ENO        │
│                             │
│ → MIV   → RBV  → RHM        │
│                             │
│ → SEND        → KEYBOARD    │
│  ******** SENT ! ********   │
├─────────────────────────────┤
│                       MAIN  │
└─────────────────────────────┘
```

FIGURE G-5.   THE LOCATION IDENTIFIER (LOCID) MENU

```
┌─────────────────────────────────────────┐
│          TERMINAL FCST : AGC              │
│                                           │
│      A    B    C    D    E    F    G      │
│                                           │
│      H    I    J    K    L    M    N      │
│                                           │
│      O    P    Q    R    S    T    U      │
│                                           │
│      V    W    X    Y    Z                │
│                                           │
│   → CLR    → BKS      → SPC   → SEND       │
│                                           │
│      ******** SENT ! ********             │
│───────────────────────────────────────────│
│                                    MAIN   │
└─────────────────────────────────────────┘
```

FIGURE F-6.   THE KEYBOARD MENU

```
┌─────────────────────────────────────────┐
│            USER SET UP                    │
│                                           │
│                                           │
│   →    AUDIO DEMO                         │
│                                           │
│   →    LOGO                               │
│                                           │
│   →    TONES ON  →  TONES OFF             │
│                                           │
│   →    SELF TEST      RUNNING             │
│                       PASSED              │
│                                           │
│───────────────────────────────────────────│
│   DARK    BRIGHT        MAIN              │
└─────────────────────────────────────────┘
```

FIGURE G-7.   THE USER SET UP MENU

```
┌─────────────────────────────────────────┐
│          RECEIVED MESSAGES                │
│      ALT ASSIGN      1333 UNA             │
│      WND/TMP   ACY 1343 ACK               │
│      T FCST    ACY 1437 ACK               │
│      SURF OB   ACY 1438 ACK               │
│      SURF OB   AGC 1445 ACK               │
│      PIREP     ACY 1510  ACK              │
│      PIREP     MIV 1512  ACK              │
│      FREQ CHANGE   1515  WIL              │
├───────────────────────────────────────────┤
│          MSG LST        MAIN              │
└─────────────────────────────────────────┘
```

FIGURE G-8. A TYPICAL MESSAGE LIST FORMAT

```
┌─────────────────────────────────────────┐
│                                           │
│       TERMINAL FCST  DQO                  │
│       20TH 1800Z TO 1800Z                 │
│     1800Z-0100Z                           │
│           SKY: 20 OVC                     │
│     0100Z-1200Z                           │
│           SKY: 15 OVC                     │
│     1200Z-1800Z                           │
│        MVFR                               │
│                                           │
├───────────────────────────────────────────┤
│                           MAIN            │
└─────────────────────────────────────────┘
```

FIGURE G-9. A TYPICAL TERMINAL FORECAST FORMAT

Surface Observation (SA) - A report of current ground weather at a selected station; includes sky conditions, ceiling, visibility, weather, obstructions to vision, wind direction/speed, altimeter setting, and additional remarks (see figure G-11).

PIREPS (UA) - Pilot reports of inflight conditions which may include information on sky cover, flight visibility, flight weather, and indications of icing or turbulence, etc. (see figure G-12).

AIR TRAFFIC CONTROL.

Altitude Assignment (AA) - An ATC command to change to assigned altitude. The command may also contain time or crossing references and, if required, an altimeter setting (see figure G-13).

Frequency Change (FC) (or Sector Hand-off) - An ATC command to a pilot to change to a new traffic control agency/center frequency (see figure G-14).

DATA LINK SWITCHING LOGIC

WEATHER.

1. Downlink WX Request. On the MAIN menu, select the WX product of interest; a menu of LOCID'S appears. The service requested is displayed above the menu of available locations. After selecting the desired location, the three letter identifier is displayed next to the service requested; e.g., TERM FCST FOR: AGC (Allegheny County). Once a location is entered, touch the "SEND" command. A confirmation that the request has been sent (***** SENT! *****) appears briefly on the display.

    a.   Subsequent selections of a location in the LOCID menu clears the previous location entered.

    b.   If desired, an alternative mode of selection exists through the "KEYBOARD" command on the LOCID menu. The KEYBOARD option was not used in the evaluation.

    c.   Once "SEND" has been selected, the LOCID menu remains until selecting "MAIN."

    d.   After a request and upon returning to MAIN, a "?" and the location requested will appear next to the requested service to denote a pending WX message (see figure G-15).

```
            WIND/TEMP ALOFT RBV

        20TH 1800Z TO 1800Z
         ALT      DIR    SPD    TMP

         6000     000     O      *


         9000     240     15     -6


         12000    240     20    -11
        _____

                                      MAIN
```

FIGURE G-10.   A TYPICAL WINDS/TEMPERATURE ALOFT FORMAT

```
            SURFACE OBS        DQO

        TIME: 1254Z

        SKY :20 OVC   VIS :5

        TEMP :49 DEW PT :38

        WIND:210/5

        ALTIMETER: 30.19


        _____

                                      MAIN
```

FIGURE G-11.   A TYPICAL SURFACE OBSERVATION FORMAT

```
            PIREP                    RBV
       TIME: 1335Z
       ACFT: KC135 FL280
       LOC :360 30NM RHM
       WIND:255/37 TMP:-30



                                    MAIN
```

FIGURE G-12. A TYPICAL PILOT REPORT (PIREP) FORMAT

```
         ALTITUDE ASSIGNMENT


         CLIMB AND MAINTAIN


         ALTITUDE:   16000


         ALTIMETER:  29.98


           WILCO        UNABLE
```

FIGURE G-13. AN ALTITUDE ASSIGNMENT FORMAT

```
        FREQUENCY CHANGE


    CONTACT UDS CENTER ON


    NEW FREQ:   122.50


    CURRENT FREQ:  123.50
_____

       WILCO      UNABLE
```

FIGURE G-14. A FREQUENCY CHANGE FORMAT

```
       DATALINK MAIN MENU
    →    TERMINAL FCST    ? AGC
    →    SURFACE OBS
    →    WIND/TEMP
    →    REQUEST PIREP


    →    MESSAGE LIST
    →    USER SET UP
_____

```

FIGURE G-15. A FORMAT SHOWING A PENDING WEATHER MESSAGE

e. If a request for WX is not available, "WX NOT AVAILABLE" is briefly displayed near the bottom and the system returns to MAIN automatically.

2. <u>Receive Uplink WX Message</u>. A three beep tone and the message "TOUCH FOR WX MESSAGE" annunciate the arrival of requested WX data (see figure G-16). Upon touching "TOUCH FOR WX MESSAGE," the WX information is displayed.

a. Within each WX message (see WX formats) the word "MAIN" is displayed at the bottom right. Touching "MAIN" will toggle the system back to MAIN.

b. The "?" will disappear (in MAIN) next to the WX product after viewing the WX information. The LOCID remains until a different location is requested for that service.

c. If, while waiting for a WX message, an ATC message arrives, the prompt "TOUCH FOR WX MESSAGE" will not appear until after responding to the ATC instruction. If an ATC message arrives before completing a request for WX, the request will require complete reinitiation.

AIR TRAFFIC CONTROL.

1. Receive Uplinked ATC Instruction. A two beep tone (distinctive from WX tone) and "TOUCH FOR ATC MESSAGE" (in reverse video) annunciate the arrival of ATC instructions (see figure G-17). Upon touching "TOUCH FOR ATC MESSAGE", the ATC message is displayed along with the options "WILCO" and "UNABLE."

a. Upon touching "WILCO", "***** SENT! *****" is displayed momentarily.

b. Upon touching "UNABLE", "CONTACT ATC VIA RADIO" is displayed momentarily, followed by "***** SENT! *****" (see figure G-18).

c. After "***** SENT! *****", is displayed (as in 1a and 1b), the command MAIN replaces the WILCO UNABLE line. The ATC message stays on the screen until MAIN is selected.

d. If more than one ATC message is queued, subsequent ATC messages will not appear until the current ATC message has been WILCOed or UNABLEd. Every ATC message in the queue requires touching the TOUCH FOR ATC MESSAGE prompt.

```
┌──────────────────────────────────────────────┐
│              DATALINK MAIN MENU                │
│      ─→      TERMINAL FCST        AGC          │
│      ─→      SURFACE OBS                       │
│      ─→      WIND/TEMP                         │
│      ─→      REQUEST PIREP                     │
│                                                │
│      ─→      MESSAGE LIST                      │
│      ─→      USER SET UP                       │
├──────────────────────────────────────────────┤
│          TOUCH FOR WX MESSAGE                  │
└──────────────────────────────────────────────┘
```

FIGURE G-16. A FORMAT SHOWING AN AVAILABLE WEATHER MESSAGE

```
┌──────────────────────────────────────────────┐
│              DATALINK MAIN MENU                │
│      ─→      TERMINAL FCST        AGC          │
│      ─→      SURFACE OBS                       │
│      ─→      WIND/TEMP                         │
│      ─→      REQUEST PIREP                     │
│                                                │
│      ─→      MESSAGE LIST                      │
│      ─→      USER SET UP                       │
├──────────────────────────────────────────────┤
│          TOUCH FOR ATC MESSAGE                 │
└──────────────────────────────────────────────┘
```

FIGURE G-17. A FORMAT SHOWING A PENDING ATC MESSAGE

```
┌─────────────────────────────────────────────────────┐
│  ┌───────────────────────────────────────────────┐   │
│  │                                               │   │
│  │           ALTITUDE ASSIGNMENT                 │   │
│  │                                               │   │
│  │                                               │   │
│  │           CLIMB AND MAINTAIN                  │   │
│  │                                               │   │
│  │           ALTITUDE:   16000                   │   │
│  │                                               │   │
│  │           ALTIMETER:  29.98                   │   │
│  │                                               │   │
│  │           CONTACT ATC VIA RADIO               │   │
│  │                                               │   │
│  └───────────────────────────────────────────────┘   │
│                                                       │
└─────────────────────────────────────────────────────┘
```

FIGURE G-18.   THE DISPLAY AFTER AN UNABLE RESPONSE TO AN ATC MESSAGE

MESSAGE LIST.

A list of received transactions, both ATC and WX, can be viewed
in the MESSAGE LIST upon touching the "MESSAGE LIST" line in the
MAIN menu (see figure G-8). The "MAIN" command appears on the
bottom right of the MESSAGE LIST menu.

1. Displayed in columnar form are abbreviations of each WX
service followed by the LOCID, time received, and a three-letter
status identifier of the transaction. An ACK
(Acknowledge) or NDA (No Data Available) distinguish those WX
messages that were available (and seen) from those which were not
available for the station requested.

2. An abbreviation of ATC messages received were followed by the
time received and a three-letter description of the
transaction: WIL (WILCO) and UNA (UNABLE).

3. If desired, the complete message was viewable by touching the
appropriate line in the list.

4. An "MSG LST" command appears to the left of the MAIN command
on the bottom line of each message selected through the MESSAGE
LIST. This allows one to return to the MESSAGE LIST menu to
retrieve another message or return to MAIN.

5. Eight messages can be displayed/retrieved from the MESSAGE LIST. Once eight message transactions have been made, each succeeding transaction will replace the existing messages in a top-down fashion.

USER SET UP.

Brightness level of the display was adjustable through the USER SET UP menu (retrieved from MAIN menu). Other options on the USER SET UP menu, Audio Demo, Logo, and Tones on/off were available but not used in the evaluation.

GENERAL

1. The system did not permit multiple WX requests. A request for WX required completion and viewing the data prior to making another request.

2. When TOUCH FOR WX MESSAGE or TOUCH FOR ATC MESSAGE appeared, all other screen functions were disabled.

3. If a TOUCH FOR WX MESSAGE is displayed and an ATC message arrives, the message TOUCH FOR ATC MESSAGE replaces the WX message. After completion of the ATC transaction, the WX message reappeared.

4. With all touch activity, a one-beep tone provided audio feedback.

5. Where shown on the formats, an "→" represented a selectable item. The bottom line, however, did not have an "→" indication. The higher level commands that appeared on the bottom line of the display were enclosed by a thin-lined rectangle, allowing the area to be more discriminable.

APPENDIX H

DETAILED AIRCREW RESULTS

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LIST OF ILLUSTRATIONS

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GENERAL

The test was conducted over 2 days. Six data runs were completed each day at each location for a total of 24 runs. Each pilot/crew flew three runs; two with Data Link and one using voice (as a baseline control condition). The ground Data Link group also allowed time for up to four supplemental runs. The airborne group at NASA participated in one of these runs because of a technical problem in a data run. The airborne group at the FAA Technical Center participated in two of these runs for additional data (no technical problems occurred).

An attempt was made to exercise each of the four weather services during each run. The number and type of Air Traffic Control (ATC) messages were, however, variable. Table H-1 presents the ATC and weather services exercised in each run for GAT. Table H-2 presents this information for the B-727. A summary of Data Link voice/weather ATC usage for the GAT and B-727 is presented at the bottom of table H-2 (also note the number of voice callbacks).

TABLE H-1. GAT ATC/WEATHER SERVICES EXERCISE BY RUN

Run	1	2	3	4	5	6	7	8	9	10	11	12
ATC												
Alt. Assign	2	3	3	1	2	2	3	2	1	2	1	3
Freq Chg	1	1	1	1	1	1	1	1	1	1	1	1
Free Text	0	1	0	0	0	2	0	2	0	2	2	1
Weather												
T Fcst	1	1	1	1	1	1	1	1	1	1	1	1
S Obs	1	1	1	1	1	1	1	1	0	1	1	1
Wind/Temp	1	1	1	1	1	1	1	1	1	1	1	1
PIREP	1	1	1	1	1	1	1	1	1	1	1	1

TABLE H-2.   B-727 ATC WEATHER/SERVICES EXERCISED BY RUN

Run	1	2	3	4	5	6	7	8	9	10	11	12
ATC												
Alt. Assign	7	3	6	4	3	9	5	5	6	8	6	6
Freq Chg	3	3	4	3	2	2	3	4	3	2	2	1
Free Text	7	2	3	4	0	2	1	1	3	8	2	5
Weather												
T Fcst	1	1	1	1	0	0	1	1	0	0	1	1
S Obs	1	1	1	1	1	1	1	1	1	1	1	1
Wind/Temp	0	1	1	1	0	0	1	1	1	0	0	1
PIREP	0	0	0	1	0	0	0	1	0	1	1	1

Totals	WX Data Link	57	ATC Data Link	106
(Tables 1	Wx Voice	22	ATC Voice	75
and 2)	- callbacks	3	- callbacks	10

OBJECTIVE

The objective measures of performance during the evaluation were various time intervals. Definitions of the critical time intervals (in both Data Link and voice) follow. Figure H-1 presents the time interval definitions in a graphic form for clarity.

TIME INTERVAL DEFINITIONS.

Weather.

MCT - Message Creation Time.

Voice   - The interval begins with the pilot activating the mike switch (PTT-Push To Talk-ON), during which a request for weather is made, and ends when the pilot releases the mike switch (PTT-OFF).

Data Link - The interval begins when pilot touches one of four WX products on the MAIN menu; included is the time required in selecting the appropriate LOCID. The interval ends upon touching "SEND" in the LOCID menu.
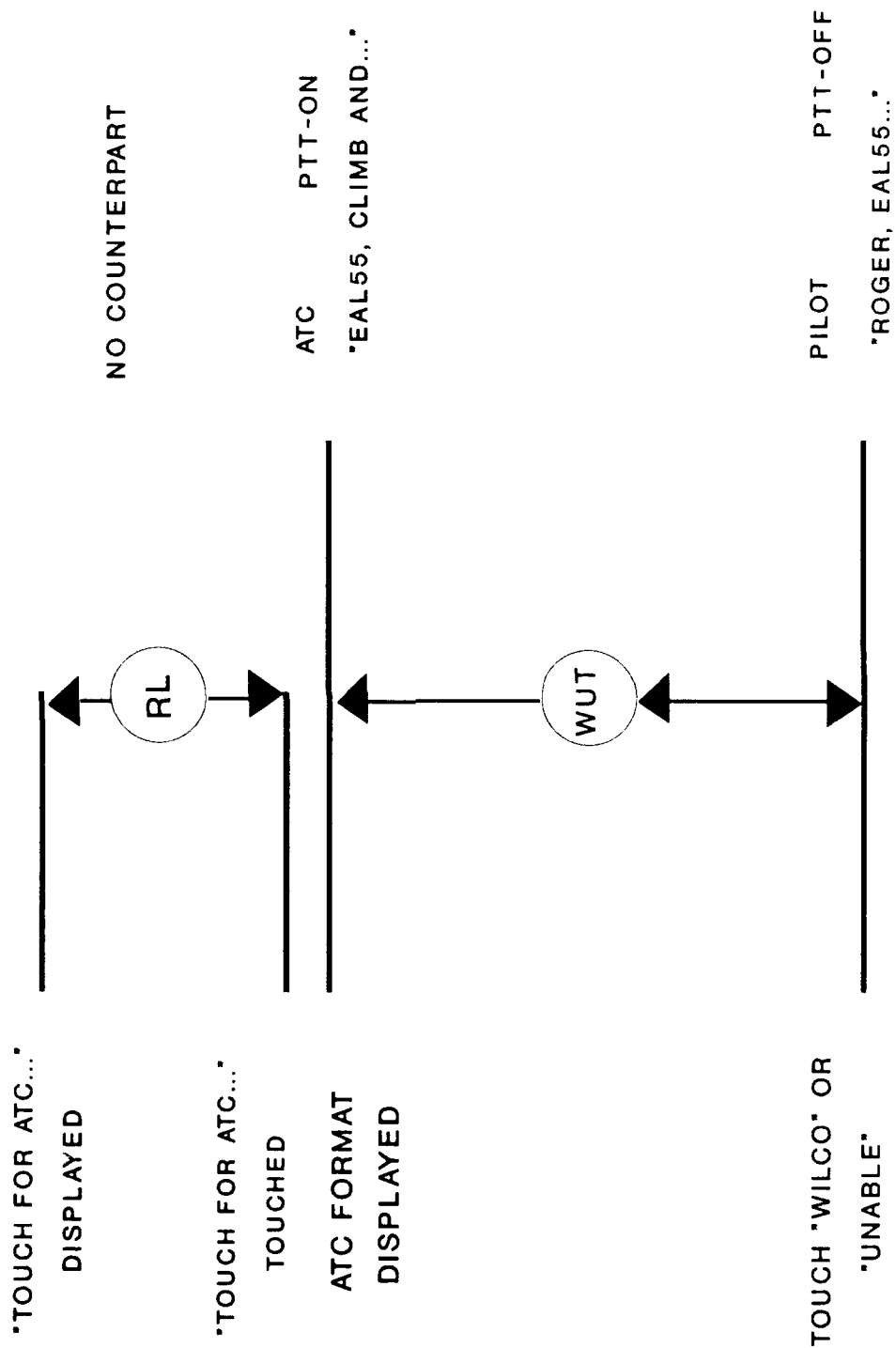
FIGURE H-1. TIME INTERVALS DEFINED (SHEET 1 OF 2)

WEATHER

DATA LINK

VOICE

DATA LINK

SELECT WX FROM MAIN

TOUCH 'SEND' IN LOCID MENU

'TOUCH FOR WX...' DISPLAYED

'TOUCH FOR WX...' TOUCHED
WX FORMAT DISPLAYED

TOUCH 'MAIN' IN WX FORMAT

VOICE

PILOT   PTT-ON
'N8417P REQUEST PIREP....'

PILOT   PTT-OFF
'...FOR DUPONT AREA'

FSS   PTT-OFF
'I HAVE REQUEST, OVER'

PILOT   PTT-ON
'GO AHEAD'

FSS   PTT-ON
'PIREP REPORTED NEAR...'

FSS   PTT-OFF
'...MODERATE TURBULENCE'

MCT   ST   RT   MPT
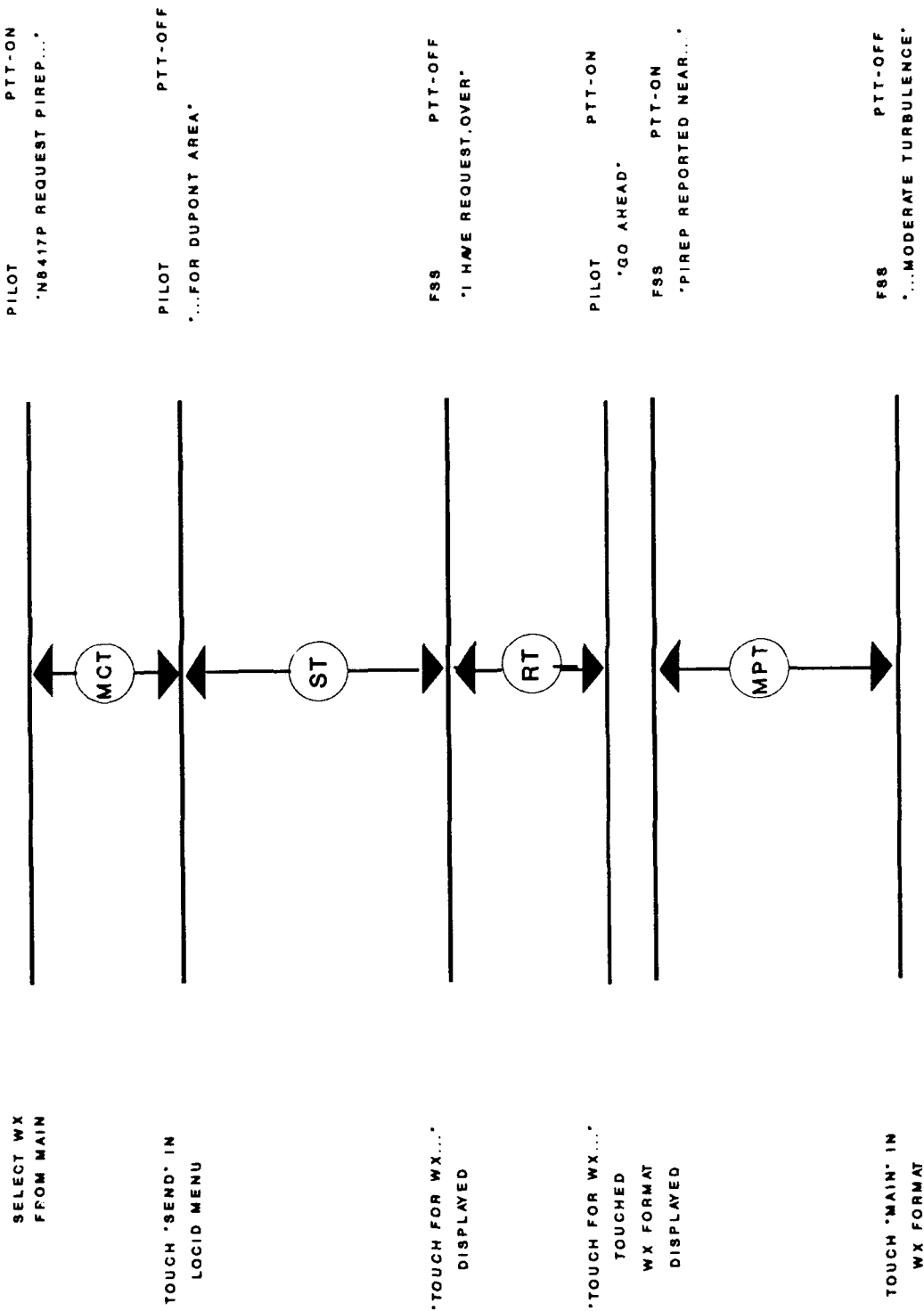
FIGURE H-1. TIME INTERVALS DEFINED (SHEET 2 OF 2)

ST - System Time.

Voice - The interval begins with the release of the mike switch in MCT and ends with the FSS/Flight Watch release of the mike switch after announcing that WX is available, i.e., "I have your request, over."

Data Link - The interval begins with touching "SEND" in MCT and ends when "Touch for WX Message" is displayed.

RL - Response Latency.

Voice - The interval begins with the FSS/Flight Watch release of mike switch and ends when the pilot presses mike switch to announce, "Yes, Flight Watch, go ahead."

Data Link - The interval begins with the annunciation of "Touch for WX Message" and ends when the pilot touches the prompt "Touch for WX Message."

MPT - Message Processing Time.

Voice - The interval begins when FSS/Flight Watch activates the mike to "read" the WX message to the pilot and ends when FSS releases the mike after reading the complete message. Any repeats of information required added to the time as appropriate.

Data Link - The interval begins with the appearance of requested weather on the screen and ends when the pilot touches MAIN menu.

Air Traffic Control

RL - Response Latency.

Voice - No counterpart to Data Link.

Data Link - The interval begins when "Touch for ATC Message" appears on the display and ends when the pilot touches the prompt "Touch for ATC Message."

WUT - WILCO/UNABLE Response Time.

Voice - The interval begins with controller's PTT-ON (during which the ATC instruction is delivered) and ends with the pilot's release of the mike switch after acknowledging the instruction. If the pilot requested a "SAY AGAIN," this time was included.

Data Link - The interval begins with the appearance of the ATC Instruction on the display screen and ends with the touch of WILCO or UNABLE.

The following provides an example of the voice transactions made
between the pilot and FSS/Flight Watch as implemented in the test
during voice runs.

Action		Pilot:
PTT-ON	(Start of MCT)	"Atlantic City Weather, 17P requesting Dupont (DQO) Terminal Weather."
PTT-OFF	(End of MCT) (Start of ST)	

Weather:

PTT-ON		"17 Papa, please stand by."
PTT-OFF		

PTT-ON		"17 Papa, this is Atlantic City Weather with your request, over."
PTT-OFF	(End of ST) (Start of RL)	

Pilot:

PTT-ON	(End of RL)	"Atlantic City Weather, go ahead."
PTT-OFF		

Weather:

PTT-ON	(Start MPT)	"17P, Dupont Terminal Weather for 18Z to 01Z, sky coverage at 2,000 feet, over cast. For 01Z to 12Z, sky coverage at 1500 feet, overcast. For 12Z to marginal VFR (Visual Flight Rules) is expected. Current Atlantic City altimeter 29.93."
PTT-OFF	(End of MPT)	

Pilot:

PTT-ON		"Atlantic City Weather, 17 Papa, I copy Dupont Terminal Weather." - Pilot may read back weather for confirmation at this point.
PTT-OFF		

Figure H-2 presents the pilot time response data to ATC, i.e., WILCO or UNABLE time differences between Data Link and voice by GAT and B-727. Figure H-3 presents this information broken down by each of the possible ATC services. Figure H-4 presents total pilot interaction time data with weather services (message creation time + response latency + message processing time). The Overall weather - Pilot Response time data by Data Link and voice (by GAT and B-727) are presented in figure H-5. Figure H-6 presents the GAT individual weather services data. Figure H-7 presents the B-727 individual weather services data. The overall and individual weather services time data (Average and Standard deviation) for WX/ATC for GAT and B-727 are presented in tables H-3 and H-4, respectfully.

SUBJECTIVE

The subjective data will be presented in this section. The questionnaire was administered to four general aviation pilots and four airline crews. The numerical average (AVG) and standard deviation (STD) was calculated for each rating type answer. The AVG and STD was calculated for the GAT group, the B-727 group, and the combination of groups. The standard rating scale used in many of the questions is presented in table H-5.

The questions, ratings summary, and pilot comments are presented below. Each question is preceded by a brief observations section. Unless otherwise noted, the statistics were conducted on the combined group of 12 pilots. Limited sample size prevented any tests to compare the general aviation and airline pilot responses.

A Chi-square one sample test (Statistical Analysis in Psychology and Education, 2nd Edition, 1966 G.A. Ferguson, McGraw-Hill) was conducted on the data from questions 4, 25-28, and 30. The null hypothesis for all questions was: There is no difference in the expected number of responses in each category, and any observed differences are merely chance variations to be expected in a random sample from the rectangular distribution where all frequencies are equal. All p values were at or below the 0.05 level of significance. This would indicate the presence of a preferred response (Yes-No) within the choices. The test statistics are presented at the end of each question.

A Kolmorgorov-Smirnov one sample test (Ferguson) was conducted on the pooled data from questions 1, 9, 12, 13, 17, and 22. The null hypothesis (for these questions) is that there is no difference in the expected number of responses to each rating number, and any observed differences are merely chance variations to be expected in a random sample from the rectangular distribution where all frequencies are equal. The use of this test reflects the nature of the data; i.e., rating type data. The Chi-square test was used with yes-no type data. Table H-6

H-7

DATALINK VS. VOICE
Overall – ATC

Time Seconds

12 —
10 —
8 —
6 —
4 —
2 —
0 —

GAT

B-727

WILCO – UNABLE TIME
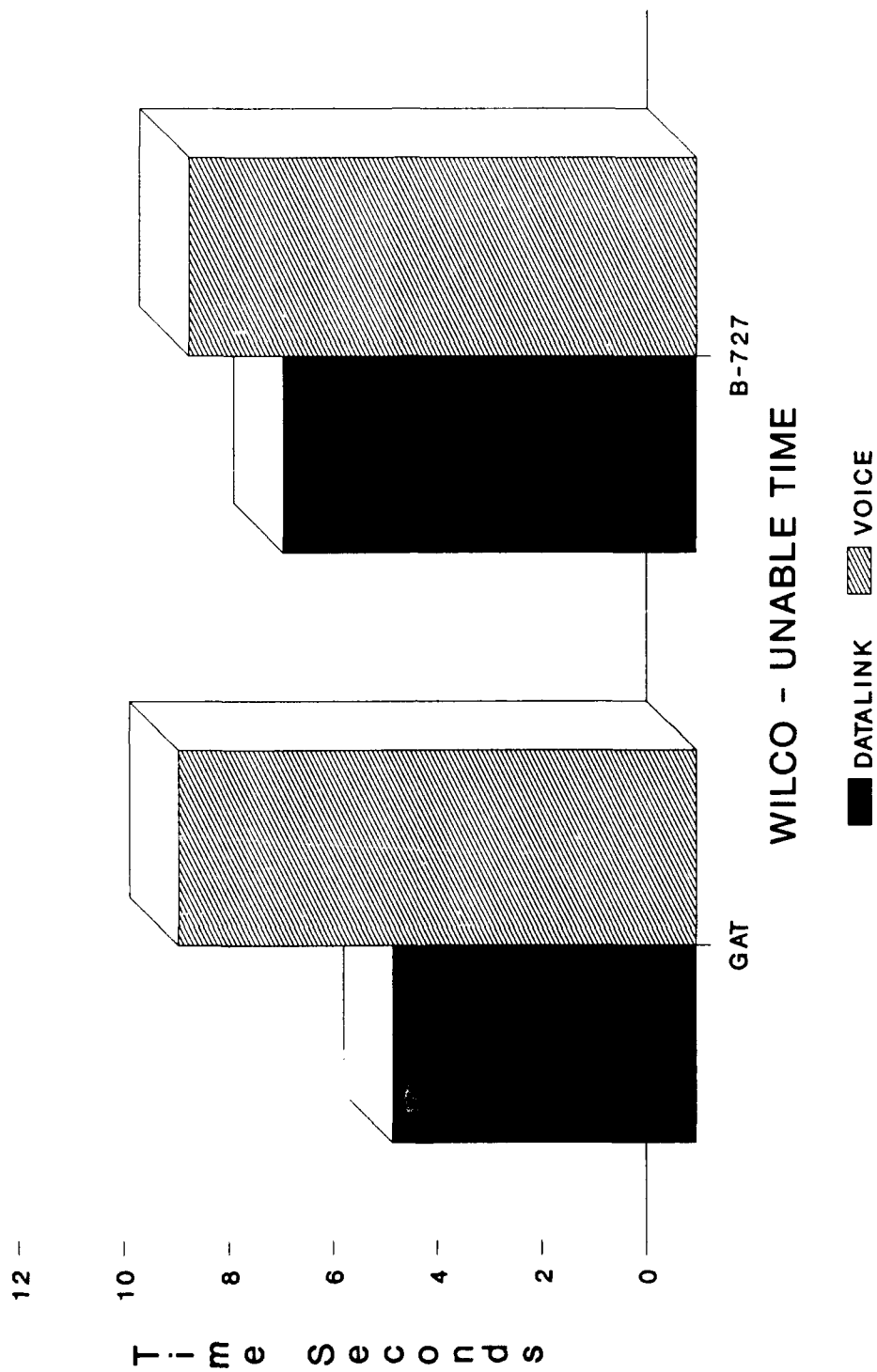
■ DATALINK   ▨ VOICE

FIGURE H-2. PILOT TIME RESPONSE TO ATC

DATALINK VS. VOICE
ATC Services

WILCO - UNABLE TIME
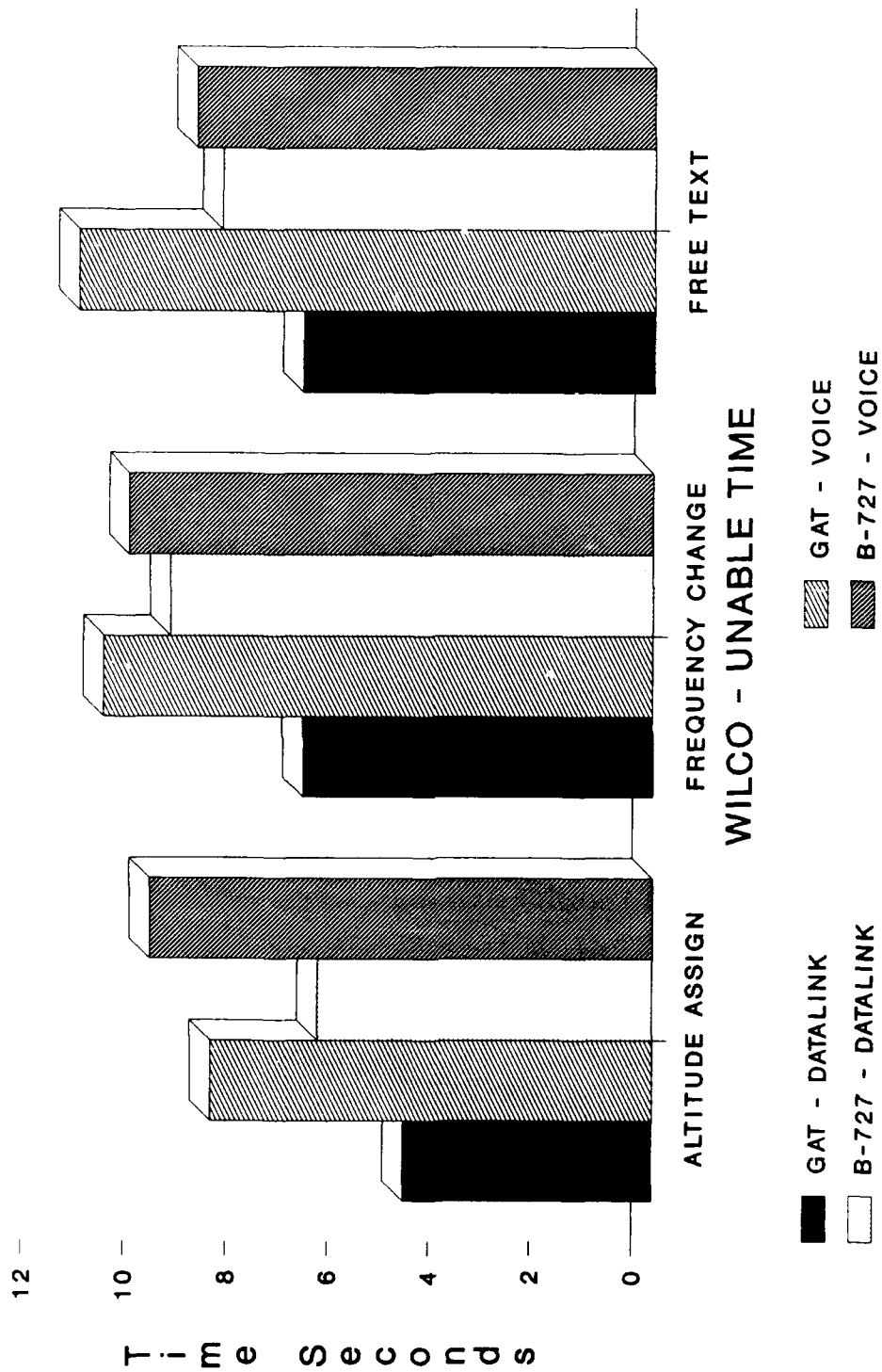
FIGURE H-3. ATC SERVICES - PILOT TIME RESPONSE

Data Link vs. Voice

TOTAL PILOT INTERACTION TIME

TPIT = MCT + RL + MPT

COMBINED WEATHER SERVICES DATA

DL   VOICE
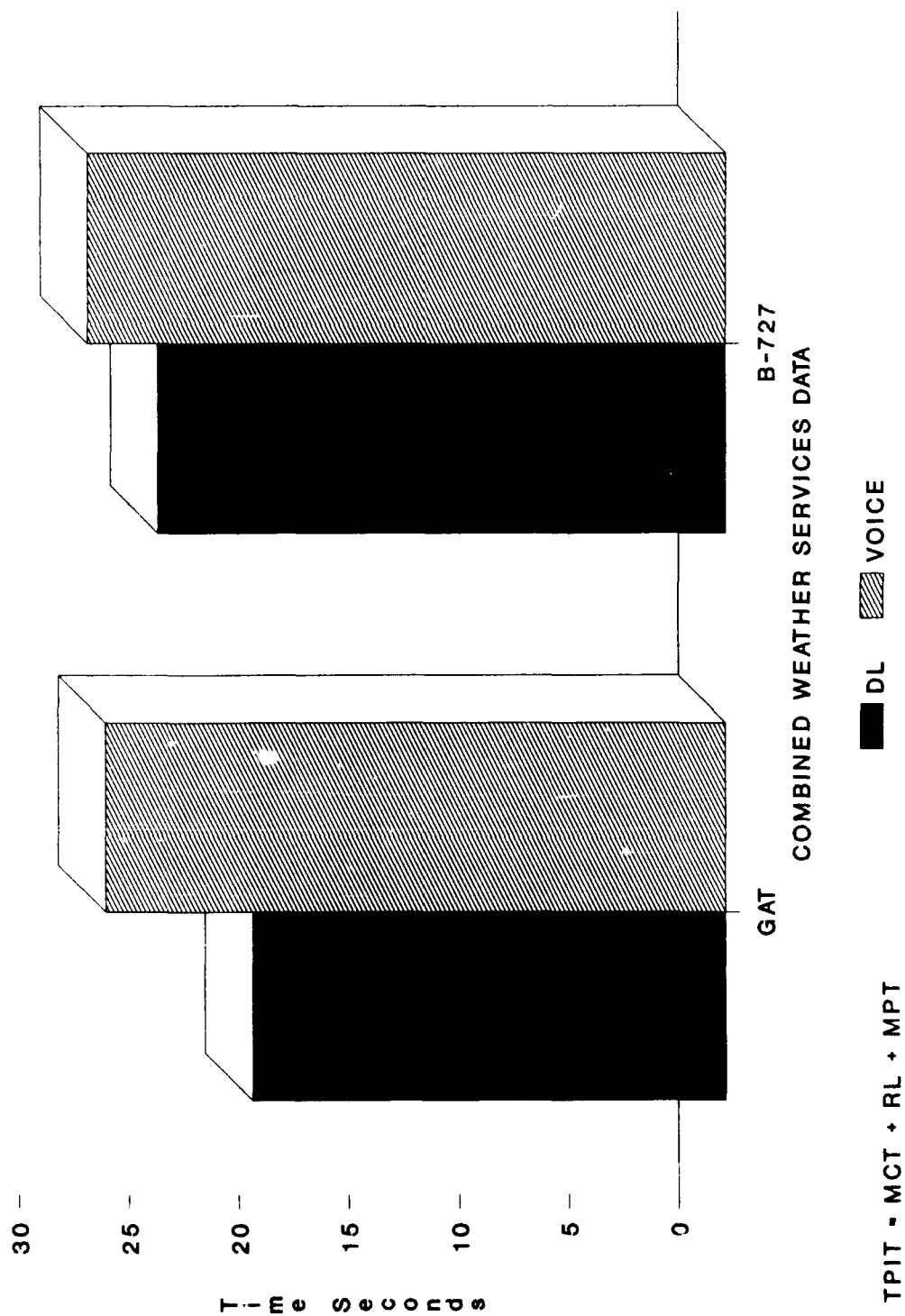
FIGURE H-4. PILOT INTERACTION TIME

DATALINK VS. VOICE
Overall – Weather
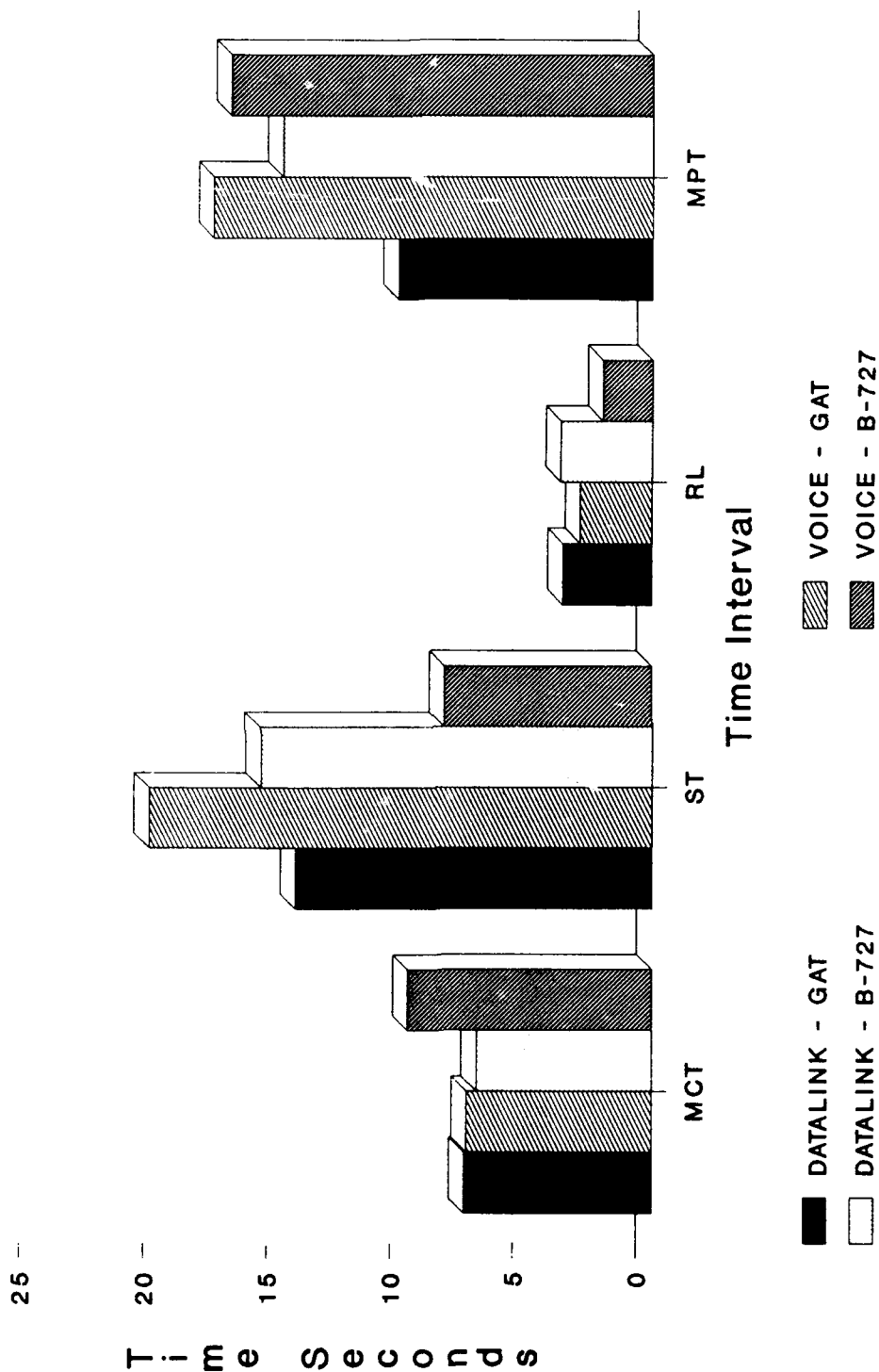
FIGURE H-5. WEATHER – PILOT TIME DATA

GAT DATALINK VS. VOICE
TERMINAL FORECAST / SURFACE OBSERVATIONS
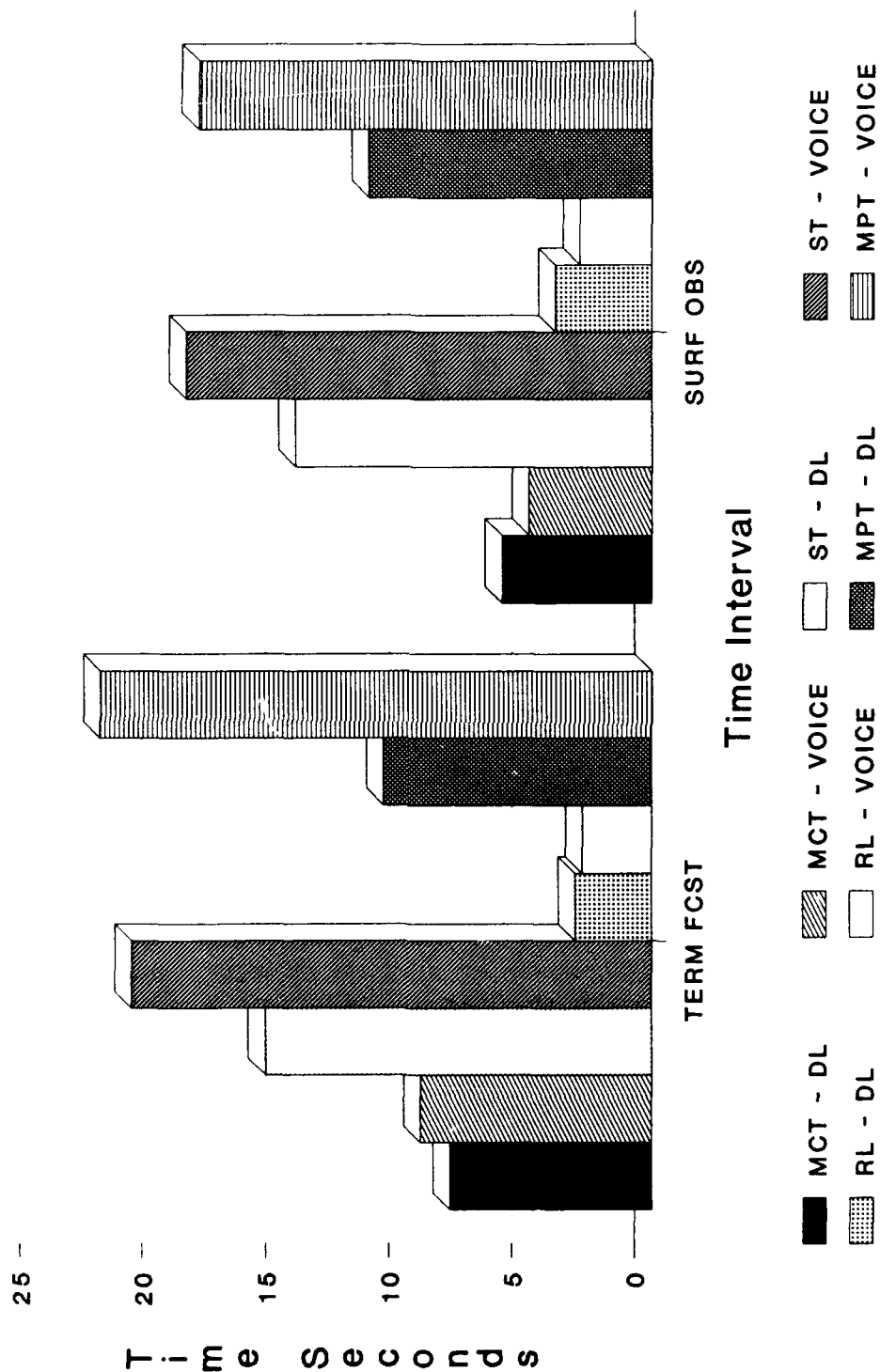
FIGURE H-6. GAT WEATHER RESPONSE DATA (SHEET 1 OF 2)

GAT DATALINK VS. VOICE
WIND/TEMP / PIREPS

FIGURE H-6. GAT WEATHER RESPONSE DATA (SHEET 2 OF 2)
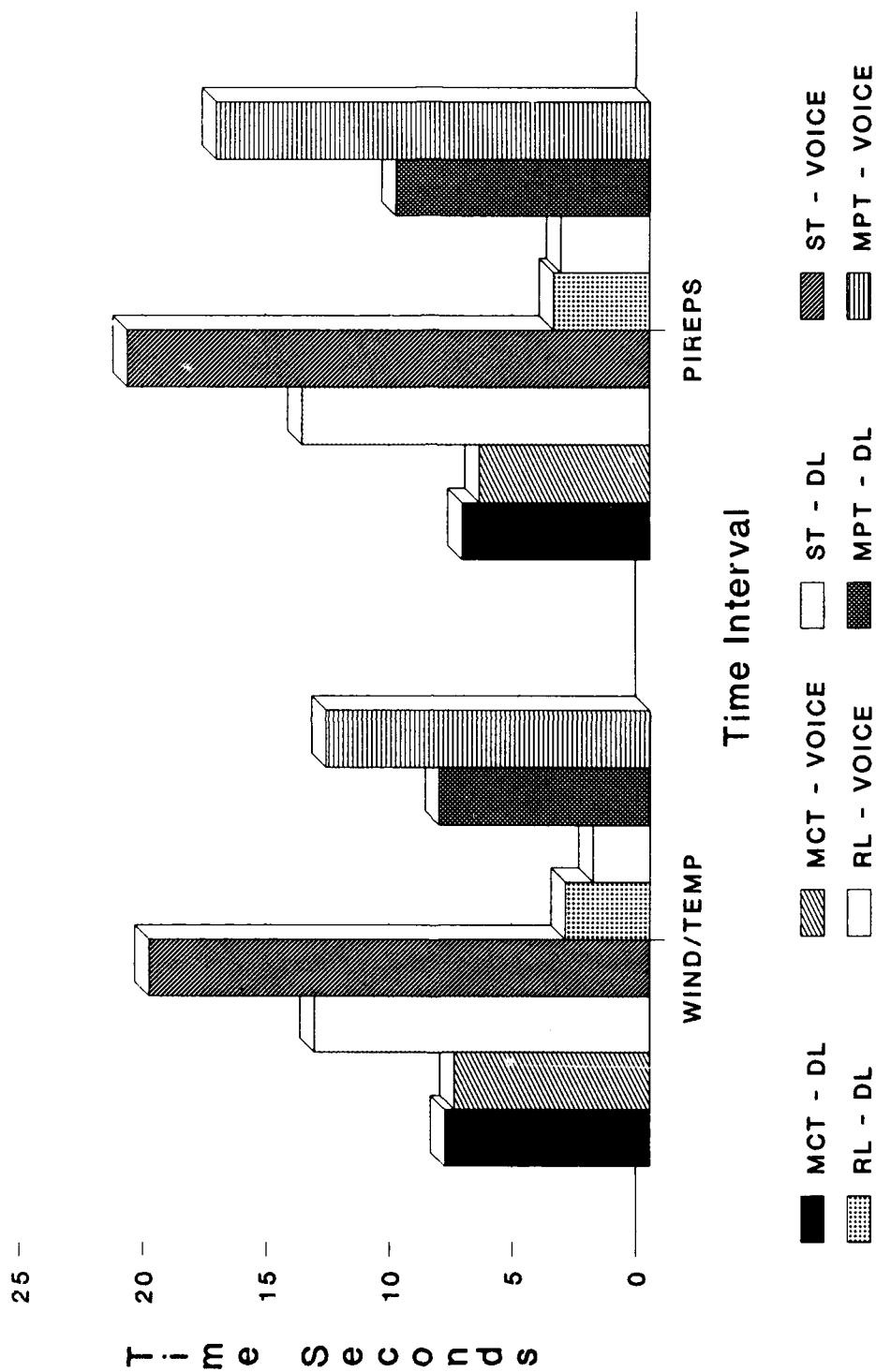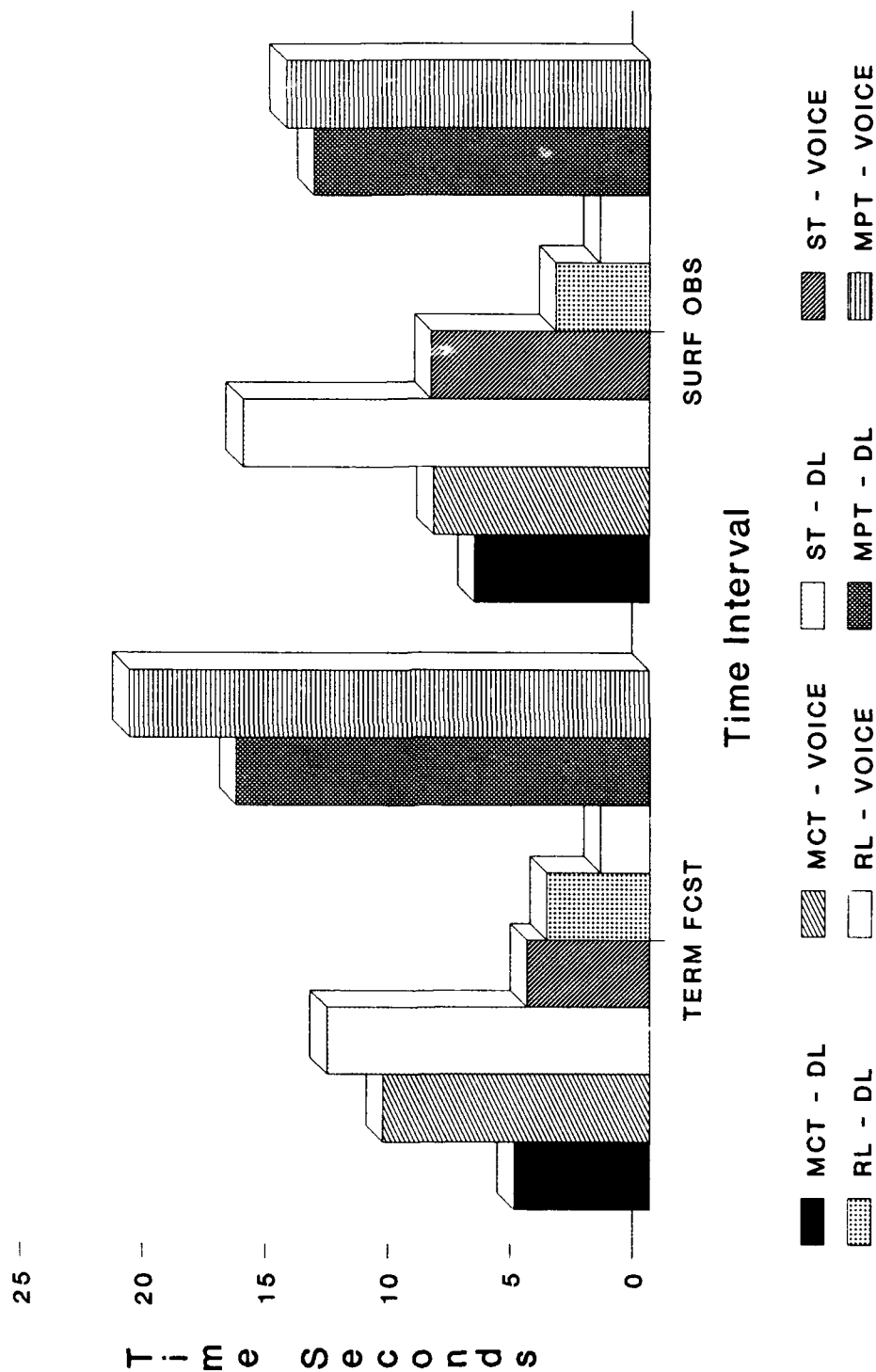
FIGURE H-7. B-727 WEATHER RESPONSE DATA (SHEET 1 OF 2)

B-727 DATALINK VS. VOICE
WIND/TEMP / PIREPS
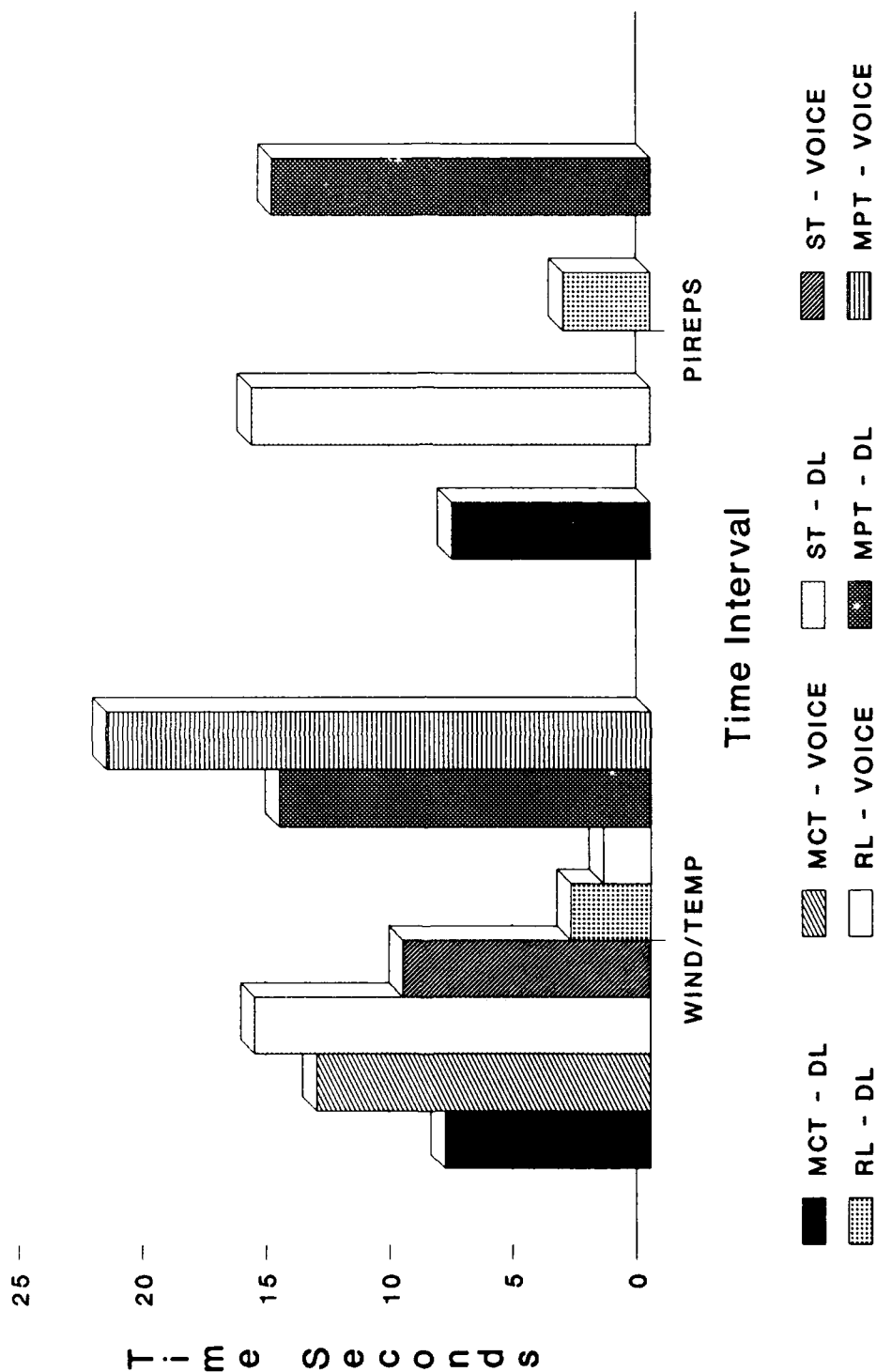
FIGURE H-7. B-727 WEATHER RESPONSE DATA (SHEET 2 OF 2)

TABLE H-3. GAT TIME DATA (WX AND ATC)

Time in Seconds

Data Link - Weather

	MCT Avg	MCT Std	ST Avg	ST Std	RL Avg	RL Std	MPT Avg	MPT Std
FT	8.2	4.9	15.7	1.7	3.1	0.5	10.9	4.1
FD	8.3	4.6	13.6	0.9	3.4	1.4	8.5	2.6
UA	7.6	4.5	14.1	1.6	3.9	1.2	10.3	4.1
SA	6.1	2.4	14.5	1.9	3.9	2.2	11.5	3.4
Overall	7.6	9.1	14.5	1.7	3.6	1.4	10.3	3.6

Voice - Weather

	MCT Avg	MCT Std	ST Avg	ST Std	RL Avg	RL Std	MPT Avg	MPT Std
FT	9.4	2.5	21.1	0.2	2.8	0.4	22.4	1.4
FD	7.9	2.1	20.3	1.5	2.3	0.2	13.1	0.8
UA	6.9	2.7	21.2	0.6	3.6	2.0	17.6	1.5
SA	5.0	1.0	18.9	1.7	2.9	0.3	18.4	1.5
Overall	7.5	2.6	20.4	1.4	2.9	1.1	17.8	3.7

Data Link - ATC

	RL Avg	RL Std	WUT Avg	WUT Std
AA	3.7	0.7	4.9	1.2
FC	3.6	0.4	6.9	1.3
Free Text	3.9	0.7	6.9	2.4
Overall	3.7	0.6	5.8	1.8

Voice - ATC

	RL Avg	RL Std	WUT Avg	WUT Std
AA			8.7	2.1
FC	n/a		10.8	3.0
Free Text			11.3	4.5
Overall			9.9	3.1

TABLE H-4. B-727 TIME DATA (WX AND ATC)

Time in Seconds

Data Link - Weather

	MCT Avg	MCT Std	ST Avg	ST Std	RL Avg	RL Std	MPT Avg	MPT Std
FT	5.5	2.0	13.2	2.2	4.2	0.7	16.9	10.3
FD	8.3	4.6	16.0	5.3	3.2	0.6	15.0	6.9
UA	8.0	5.7	16.1	1.1	3.5	0.6	15.3	5.7
SA	7.1	4.6	16.6	6.2	3.8	0.8	13.7	4.8
Overall	7.1	4.1	15.9	4.8	3.7	0.7	15.0	6.6

Voice - Weather

	MCT Avg	MCT Std	ST Avg	ST Std	RL Avg	RL Std	MPT Avg	MPT Std
FT	10.9	--	5.0	--	2.0	--	21.2	--
FD	13.5	--	10.0	--	1.9	--	22.0	--
UA	--	--	--	--	--	--	--	--
SA	8.8	4.4	8.9	4.1	2.0	0.8	14.8	10.1
Overall	9.9	3.9	8.4	3.6	2.0	0.6	17.1	8.6

Data Link - ATC

	RL Avg	RL Std	WUT Avg	WUT Std
AA	3.9	1.5	6.6	2.8
FC	4.1	2.2	9.5	3.2
Free Text	4.2	2.8	8.5	3.6
Overall	4.4	3.8	7.9	3.3

Voice - ATC

	RL Avg	RL Std	WUT Avg	WUT Std
AA			9.9	5.7
FC	n/a		10.3	4.5
Free Text			9.0	4.3
Overall			9.7	5.0

TABLE H-5. STANDARD RATING SCALE

Standard Scale

7 - VERY GOOD, no changes are necessary
6 - GOOD, a few minor changes are necessary
5 - FAIRLY GOOD, a number of minor changes are necessary
4 - FAIR, both minor and major changes are necessary
3 - FAIRLY POOR, a few major changes are necessary
2 - POOR, a number of major changes are necessary
1 - VERY POOR, a complete redesign is necessary

TABLE H-6. KOLMORGOROV-SMIRNOV TEST RESULTS

Question #1	Overall Concepts	P Level
	Return to MAIN Concept	$.10 < P < .15$
Question #12	Surface Observations	
	Information Retrieval Time	$P > .20$
	Information Clarity	$.05 < P < .10$
	Return to MAIN Concept	$P > .20$
	Terminal Forecast	
	Information Retrieval Time	$.10 < P < .15$
	Return to MAIN Concept	$P > .20$
	Pilot Report	
	Amount of Information	$.05 < P < .10$
	Return to MAIN	$.05 < P < .10$
	Wind/Temp Aloft	
	Information Retrieval Time	$.05 < P < .10$
	Amount of Information	$.15 < P < .20$
	Return to MAIN Concept	$.15 < P < .20$
Question #13	Select LOCID's Menu	
	Menu of LOCID's Concept	$P > .20$
	Time Required to Input/Enter	$.10 < P < .15$
	LOCID Menu of Location Codes	$.10 < P < .15$
Question #20	MAIN Menu	
	Clutter	$.05 < P < .10$
	Amount of Information	$.10 < P < .15$
Question #22	LOCID Menu Lay-out	
	Rating	$.05 < P < .10$

presents those questions (and factors) in which the observed levels of significance (p values) were greater than 0.05. All other factors within these questions had observed levels of significance less than 0.05; this would indicate a preferred rating value. A further discussion is presented in the Observations Section of each question.

The observed level of significance or p value is the probability (assuming the null were true) of observing a value of the test statistic that is at least as contradictory to the null hypothesis, and supportive of alternative hypothesis, as the one computed from the sample data (Statistics, 1982, J.T. McClave and F.H. Dietrich, II Dellen Publishing Company). Usually, the null hypothesis will be rejected if the observed significance level is less than a fixed significance level chosen by the reader. A common significance level in the literature is 0.05.

A binomial test (McClave) was performed on question 21 (workload, five point scale); ratings of 1, 2 and, 3 were combined, as were ratings of 4 and 5. With this combination, the null hypothesis was than no difference would exist between the 1-2-3 and 4-5 categories. The results of this test are presented in question 21 Observations.

ATC SERVICES.

OBSERVATIONS.

Altitude Assignment - On all factors listed, the average rating was GOOD (6) or above. The B-727 pilots rated factors slightly lower with more variability in the responses. In general, the comments stress the fact that on-screen data reduces the chance for error.

Frequency Change - The GAT pilots, in general, rated the factors higher than the B-727 pilots. The ratings were GOOD (6) and above, except for appearance and ambiguity by B-727 pilots. This is probably related to their comments on being hard to read the numbers and the use of "Contact UDS ..." (a contact was not actually required).

Overall Concepts - The two factors were rated GOOD (>6) by both GAT and B-727 with the exception of "Return to MAIN" concept by B-727 pilots. These pilots did not like the requirement to Return to MAIN after a Data Link message was received and read. Their comments provided potential alternatives to the tested logic.

Statistical Results - All observed p values were at or below the 0.05 level of significance except the "Return to MAIN" concept which was between 0.10 and 0.15. The test indicates that the pilots had a preferred response on each factor (except "Return to MAIN"). In most cases this rating was a "6" or "GOOD." A few minor changes are necessary.

Question 1. For each of the two ATC services, rate the following factors associated with the format. Use the standard scale provided in making responses and circle the appropriate number. Please comment in the area provided (use the back of this page if necessary).

Altitude Assignment

	GAT		B-727		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	6.25	0.96	6.25	1.17	6.25	1.06
Clutter	6.5	1.0	6.0	1.2	6.17	1.11
Amount of information	7.0	0.0	6.38	1.16	6.58	0.9
Information clarity	6.25	0.5	6.25	1.39	6.25	1.14
Ambiguity	6.75	0.5	6.63	1.06	6.67	0.89
Time to interpret	6.5	1.0	6.25	1.04	6.63	0.98

Comments:

GAT Pilots

#1   I believe the first three lines could be compressed, requiring less reading; for instance:

          Altitude   Altitude
          ⌐->   L->
          16.4   7.3

#2   When altimeter setting is "missing," it should be spelled out instead of just -M-.

#4   Use of gold lettering instead ot green, not as hard on eyes.

B-727 Pilots

#1   Altitude assignments were easy to read and understand.

#2   Given by phone to Al Rehmann at Tech Center.

#4   Altitude Assignment very good--nice to see it in print--no chances for mistake. In contrast, on last run, no Data Link, one altitude assignment was misread!

#6   For an   important item of information   such   as altitude
change,   I   think the less data on the   screen   the   better,
i.e.,   only new altitude on the screen or only new   altitude and
climb or descend

#8   Much clearer than voice.

Frequency Change/Sector Hand-Off

	GAT		B-727		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	6.25	0.96	5.88	1.13	6.0	1.04
Clutter	6.25	0.96	6.0	1.07	6.08	1.0
Amount of information	7.0	0.0	6.13	0.99	6.42	0.90
Information clarity	6.5	0.58	6.5	1.07	6.5	0.90
Ambiguity	7.0	0.0	5.5	1.69	6.0	1.54
Time to interpret	6.25	0.96	6.0	1.6	6.08	1.38

Comments:

GAT Pilots:

#1   Once again, too many words to read.

#2   Having   current plus new frequency can eliminate   errors   by
pilot   misunderstanding   new   frequency   or   forgetting   old
frequency.

#4   Same as above (AA comment).

B-727 Pilots

#1   Clear   and easy to understand. Especially like   the   recall
feature.

#4   The numbers are just a bit hard to read. Had to look   twice
to make sure.

#7   Do not use the word "contact" as this implies a radio call
to center is required.   Maybe use words like "switch to"   or
"change to" when commanding a frequency change.

#8   Much clearer than voice.

Overall Concepts

	GAT Avg	Std	B-727 Avg	Std	Overall Avg	Std
WILCO/UNABLE concept	6.25	0.5	6.29	1.5	6.27	1.19
Return to Main concept	6.25	0.5	5.14	1.77	5.55	1.51

Comments:

GAT Pilots

None

B-727 Pilots

#1   I saw no specific reason to return to MAIN.   If this is necessary, perhaps it could "revert" to Main after delay time.

#3   Three attempts were made to secure WX information for ACY with no response.

#4   Not sure that I want to return to Main, except for this exercise.

#7   I recommend leaving last altitude assignment showing on screen.   It is providing useful information.   Looking at MAIN menu has no benefit.

#8   Should return to "whatever" after WILCO?

AUDITORY ANNUNCIATION.

OBSERVATIONS. In general, all pilots were satisfied with the auditory annunciation of incoming ATC Data Link messages.   Two B-727 pilots provided a MAYBE response and expressed concerns with (a) high workload situations, and (b) the startling effect the tone had.   Other comments were made concerning the tone in a real cockpit, missing the tones, and number of tones in the present cockpit.

Question   2.   The ATC services in this evaluation were ground initiated.   Given the fact that other tasks were required of you in addition to using the Data Link system, were you satisfied with the auditory annunciation of an incoming ATC service?   If not, explain your dissatisfaction.

	GAT	B-727
Yes	1,2,3,4	1,3,4,5,7,8,
No		
Maybe		2,6

Comments:

GAT Pilots

#1   I'm a little concerned that they might not be heard in a real cockpit.

#2   What happens if pilot misses first beeps because of other tasks and does not include the display in his scan?

B-727 Pilots

#1   The only problems I encountered had to do with volume levels in the simulator (727). There were no ATC audio problems.

#2   When workload high, difficult for pilot flying to stay in information loop.

#3   The auditory warning was adequate with the cockpit noise level.

#4   OK for this experiment, it was a good ear-catcher. But there are already too many bells and whistles in the cockpit. Now comes TCAS (Traffic Alert and Collision Avoidance System) chirp and DL Ding Dong. Maybe flashing screen or light will suffice.
#6   It was a bit startling. Perhaps a spectrum of three different noises for different messages could be useful.

VISUAL ANNUNCIATION.

OBSERVATIONS. The visual annunciation of ATC Data Link messages was considered acceptable. Two pilots provided a MAYBE response. One suggested flashing the entire screen and providing Master Caution--like light. The other pilot suggested a change in terminology. Concerning automatic appearance of ATC messages, the pilots were negative. Four pilots provided a MAYBE response, but did not provide sufficient comments to make a judgment here.

_____   _____.

Question 3. An incoming ATC message was visually annunciated by flashing "TOUCH FOR ATC MESSAGE" at the bottom of the screen. Was this operation logic acceptable?

	GAT	B-727
Yes	2,3,4	2,3,4,5,6,7,8
No		
Maybe	1	1

Comments:

GAT Pilots

#1   Probably flashing the whole screen as well as some sort of
master light similar to a master caution light would be an
appropriate message.

#2   Something flashing may catch pilot's eye, even if tone is
missed Sound/WILCO/Maybe Read.

B-727 Pilots

#1   While this is OK, I don't have to be told to "touch";
perhaps "message" or "clearance" would be acceptable.

#3   After the auditory warning.

#4   Accepted as good.

Or, for example, should the ATC message automatically appear?

	GAT	B-727
Yes		
No	1	1,3,4,5,6,7,8
Maybe	2,3,4	2

Comments:

GAT Pilots

#1   If you are reading a message, you might want to finish it
first.

#2   If ATC message automatically appeared, it should flash until
pilot WILCO's/UNABLE's. However, by making pilot touch screen
for   message,   they   do   not   get   into   reflex   of   Bell
sound/
Wilcox/Maybe - Read.

#3   If it were flashing and also had the audible indication.

B-727 Pilots

#1   Automatic delivery would be too easy to neglect or miss altogether.   A message alert with appropriate crew acceptance should be required.

#3   Any message should follow some sort of getting.

#4   Maybe I am just looking at a WX page and want to copy that first; or just want to take extra time before I am ready--but would like to examine this later.

#5   Pilot should be given the option.

#6   There might be something on the screen that I need at the time that it (the ATC message) would come on.

#8   Some pilot action should be necessary to further substantiate the message.

TERMINOLOGY.

OBSERVATIONS.   The WILCO/UNABLE choices were understood by all pilots.   The terminology was acceptable by all pilots except two.   This dissatisfaction centered on the use of the word "Contact..." (in a frequency change) when a contact was not required.   "WILCO" means "Roger" according to one pilot, but he indicated that, either way, there was no problem. The test statistic p value indicates a preferred choice, i.e., YES for both, part A and B.

Question   4.   After an ATC message was transmitted, you were required to make either a WILCO or UNABLE response.   Did you:

GAT

		Yes	No
(a)	Fully understand the choices as presented	1,2,3,4	
(b)	Find the terminology acceptable	1,2,3,4	

If not, specify a or b, and explain your dissatisfaction.

None

<u>B-727</u>

		Yes	No
(a)	Fully understand the choices as presented	1,2,3,4, 5,6,7,8	
(b)	Find the terminology acceptable	1,3,4,6,7,8	2,5

If not, specify a or b, and explain your dissatisfaction.

#1 You may use any phraseology you wish, but "WILCO," as I understand it, means "Roger." No problem here.

#2 Call ATC was not displayed.

#4 This is a good way to acknowledge a message understood and will comply or UNABLE.

#5 When Center told us to change a frequency, it said to contact, which to us means to talk to. It should say monitor or change frequency.

The Chi-square test yielded significance levels as follows for the differences between Yes and No answers.

4a. Chi-square = 12.0 $p < .01$
4b. Chi-square = 5.33 $p < .01$

<u>LOGIC OPTIONS</u>.

<u>OBSERVATIONS</u>. The "SENT" indication after a WILCO or UNABLE was considered desirable by almost all of the pilots. There were three MAYBE responses. One pilot stated that if the logic was such that WILCO/UNABLE did not disappear until the system accepted the "SENT" command, the display of "SENT" would be unnecessary. In general, a confirmation that the system accepted the input was considered necessary. The tested system did not display "SENT" for a long enough period of time.

Question 5. After WILCO or UNABLE, a message flashed near the bottom of the screen "SENT." Is this a desirable option? Please comment.

	<u>GAT</u>	<u>B-727</u>
Yes	1,3	1,2,3,4,5,7,8
No		
Maybe	2,4	6

Comments:

GAT Pilots

#1 Absolutely necessary. Just like ATC wants confirmation of the pilot transmitting the message, so does the pilot need to know it was sent. The "SENT" message stayed on the screen for too short a time. That is true for the WX portion too.

#2 Not really necessary. After the Message WILCO/UNABLE was sent, those two words disappeared and the MAIN option appeared. The length of time "SENT" appeared on the screen was very short. If logic was written to prevent clearing WILCO/UNABLE until message sent, then this flasher would not be needed.

#3 Some means is necessary to assure the pilot that his response was sent.

#4 Something definitely has to appear letting the pilot know the reply was transmitted.

B-727 Pilots

#1 It indicates to the user that his action has been sent.

#2 Needed as confirmation

#3 There is a need for confirmation

#4 Nice to know acknowledgement was sent. If this is recorded on each flight, it might be used to prevent any controversy later if a flight conflict results.

#6 I find the logic of a second step, i.e., press SENT, to be nonconsistent with the typical one-step response.

#7 However, I would leave the word "SENT" on the screen just in case something else happened that instant and you couldn't remember whether or not you sent it.

#8 It really is nice to know.

ATC Message Logic Options

Having the ATC message remain on screen after WILCO or UNABLE was desired by all pilots but one. This pilot's comment was, "An unnecessary motion." It is assumed the comment refers to the Return to MAIN step. This option was described as, "very desirable, reinforces message, ...can be looked at as often as necessary, etc."

Question   6. After WILCO or UNABLE, the ATC message remained
until you touched MAIN.   Is this a desirable option?   Please
comment.

	GAT	B-727
Yes	1,2,3,4	1,2,3,5,6,7,8
No		4
Maybe		

Comments:

GAT Pilots

#1   You might be ready to comply, but maybe "data dump" the
frequency or altitude.

#2   Reinforces message. If pilot unsure of altitude or heading,
allows them to reverify.

#3   Very desirable. In voice communication, you must give this
operation immediate attention so as not to forget the
message. With this Data Link format, the machine remembers for
you.

#4   It gives the pilot the option when to clear that message.

B-727 Pilots

#1   The message can be looked at as often as necessary. This is
good, especially for winds aloft and other WX data.

#2   Pilot flying might not get to see it otherwise (especially
in high workload).

#3   This is very desirable to avoid mistakes.

#4   An unnecessary motion.

#8   Why is it necessary to go to MAIN to receive a new message?
I like to see my current clearance in front of me.

REQUEST CAPABILITY OPTION.

OBSERVATIONS.   Most all pilots want to be able to request a
different altitude. About half want a frequency change request
option. The comments provide justifications for desiring the
request option, e.g., icing, turbulence. The pilots also made
suggestions for other ATC service request options that would be
desirable.

Question 7. All ATC services (in this evaluation) were ground initiated. Do you feel a need to have a request capability for either of the two ATC services?

Request capability desired for: Circle your choice(s)

	Altitude Assignment	Frequency Change
GAT	2,3,4	3,4
B-727	1,2,3,4,5,6,7,8	1,4,5,8

Comments:

GAT Pilots

#1   If it is for confirmation of assignment, no, I don't need it because it is in message recall. However, if I was given a verbal assignment and needed to recall it, as long as the ground facility put it in the computer, then I could get it via Data Link. Nice option.

#2   May want to request different altitude for winds, turbulence. Marginal call, because if icing or turbulence is too high, pilot should make PIREP and REQ Altitude Change.

#3   Pilot should be able to request altitude change and what altitude he wants. Same with frequency changes, particularly with WX.

#4   Yes, if a system could be designed for the pilot to request these items. However, it may be quicker just to use the radio.

B-727 Pilots

#1   Not really necessary; voice communication can be used for some things. The nice aspect of Data Link is its ability to cut down on, or eliminate, the oversaturation of verbiage.

#2   Necessary by voice or Data Link.

#3   There is frequently a need for altitude change due to turbulence or WX conditions.

#4   "Or Just About Anything." I feel defenseless and can't fight back! The capability for two-way communication is a must! I might have an urgent need to do something like deviating thunderstorm, getting out of turbulence, etc.

#5   Also ground control and clearance.

#6   Also other capabilities, i.e., (1) new heading for thunderstorm avoidance, (2) new routing, (3) new airspeed for turbulence.

#7   Would be nice to request a different altitude using this system.

#8   (He adds and circles)   Speed, Heading, Anything.

TIME REQUIREMENTS.

OBSERVATIONS.   For both altitude assignments and frequency changes, the time one diverts from flying to operate Data Link was considered acceptable (or minimal). No excessive responses were made; one "Depends" response was made. The "Depends" response was qualified by the comment that verbal commands may be quicker in certain situations, e.g., instrument conditions or approach to a busy airport. One pilot stated that voice communications also require diversion from flying (to the same extent as Data Link) and that, overall, Data Link is superior to writing clearances, etc.

Question 8. The Data Link system as implemented will require one to divert time/attention from the flying task. For each service, state whether the time required was: minimal, acceptable, or excessive or Depends on ...? Circle the appropriate response for each service. Please comment on those services requiring excessive time and/or, if necessary, discuss the depends on ...

Altitude Assignment	Minimal	Acceptable	Excessive	Depends
GAT		2,3,4		1
B-727	1,2,4,8	3,5,6,7		

Frequency Change	Minimal	Acceptable	Excessive	Depends
GAT	2	3,4		1
B-727	8	1,2,3,4,5,6,7		

Comments:

GAT Pilots

#1   In an intense environment (i.e., Instrument Meteorological Conditions on an approach to a busy airport), a verbal condition would be quicker to decipher. However, there may be ways to overcome it. A shorter command as presented in question 1, and maybe a WILCO/UNABLE button on the yoke or throttle.

#2   Single pilot IFR frequency change probably source of too much traffic because pilot not anticipating correct frequency or does not have pen in hand to copy new frequency.

B-727 Pilots

#1   One must realize that voice communication requires diversion from the flying task to practically the same extent as manipulation of Data Link. Overall, Data Link is <u>superior</u> to jotting notes for ATC clearances and frequency changes.

#2   Altitude assignment is critical for safety and legality. If missed by pilot flying, it could cause a critical situation. Somehow the communication of this information within the operating crew should be accomplished so there is no doubt that information is understood and acted upon.

#3   The location of the display must be such that response can be made without undue effort by the pilot, particularly for single pilot operator.

#4   (for AA) Like very much.
      (for FC) With exception of poor readability on my part, attention requirements were minimal.

#5   Anytime you have excessive workload, the flying task suffers.

#6   Could be excessive if one crew member sees the message then cancels it before the other Crew Member see it, thus prompting the second Crew Member to ask for the message to be recalled.

#8   Not once did anyone ask what did he or she say. It is very clear.

OBSERVATIONS.

The ATC-Data Link overall design was rated FAIRLY GOOD to GOOD, i.e., a number of minor changes are necessary. The comments were very positive, e.g., "...better than I thought it would be at this stage of development," "like the Data Link just the way it is." Changes suggested dealt with terminology, number of services, information flow rates, etc. The observed level of significance was less than 0.05 suggesting a preferred rating, i.e., "5," or "Fairly Good," a number of minor changes are necessary.

Question 9. Improper/incomplete system designs can result in pilot errors. Overall, how would you rate this Data Link system - ATC services design. Use the standard scale provided. If you feel design problems exist, specify the areas you find unsatisfactory, i.e., where the potential for errors is most prevalent. Please provide your suggestions on how we might redesign the system to overcome these problems.

System Design - ATC Rating

GAT		B-727		Overall	
Avg	Std	Avg	Std	Avg	Std
5.5	1.0	5.38	0.92	5.42	0.90

Problem areas/suggestions:

GAT Pilots

#1 The concept is great. The evaluation is a good start. Addition of services available needs to be evaluated, and approach and departure (i.e., high intensity) control evaluations are necessary.

B-727 Pilots

#1 The pilot flying (PF) does not "hear" clearances from ATC directly. The pilot-not-flying (PNF) operating the Data Link terminal must relay altitude, heading, and routing clearances to the PF. In a relaxed operating environment, this isn't a problem. Maybe it is or is not a problem in a high workload. I would need more experience with the system to offer a valid opinion.

#2 Phone conversation with Al Rehmann, et al. on 4/20/89.

#3 Messages received rate a 7. Information requested rate much lower. There is too much delay after requesting

information, before assurance is received that the system is in process. This applies primarily to Weather Information requested.

#4 Like this system very much. I like to see the recall of messages received (and WILCOed).

#5 I really like the Data Link just the way it is, except for the frequency change. You must distinguish between monitor and talk/contact.

#6 The following areas could be questioned: The lack of hi-tech features, i.e., flashing lights (LED), horns, and whistles. For example, say the ATC message comes on the screen. It could flash until one crew member acknowledged it and then go to steady. Then when the second crew member touched it or acknowledged it, the light or MSG could go out. I think a real limit in this system is what occurs when one crew member sees the MSG, acknowledges it, and then erases it before the second crew member sees it or absorbs it.

#7 When listing messages received, list most current at bottom. Do not list them as now, where they are not in chronological order.

#8 It is much better than I thought it would be at this stage of development. Pilot should be able to initiate calls. Tower and Ground Control must be able to use this or similar system, especially high density airports, e.g., ORD, ATL, SFO, LAX, JFK, etc.

SUGGESTED SERVICES.

OBSERVATIONS. The pilots made numerous suggestions on ATC services to be part of future Data Link designs. A few of these were heading information, various clearances, and "any clearance that ground, tower, departure, approach, or Air Route Traffic Control Center (ARTCC) controller can give now over voice should be able to do visually" (Data Link).

Question 10. The design of a major system normally goes through numerous iterations. What ATC services would you consider an absolute requirement in future designs and/or as part of operational systems?

Suggested Services:

GAT Pilots

#1 WX map and/or ground radar. Amended clearances in a combined map/alphanumeric form. Heading information. A listing

in column form of alt, headings, and frequencies (Say, maybe, the previous four listed). Turbulence, icing, thunderstorm, SIGMETS information.

#2   Clearance delivery or at least squawk, departure, initial altitude, reading.

#3   Clearance display for referral.

#4   Ground speed requests.

<u>B-727 Pilots</u>

#1   I see no reason why all services cannot be included in the Data Link system.

#2   WX Warnings--Shear, Clear Air Turbulence (CAT), Microburst, Thunderstorms, major wind gusts (changes, -- Operation restrictions.

#3   Altitude change requests.

#4   Traffic advisory and crew acknowledgement. Traffic in sight or no contact. Other ATC Advisories--Change in A/S, change in climb or descent rates. Deviations from route as cleared.

#5   Need to add ground and ATC clearance control.

#6   Alt Assign, Hdg Assign, Route Assign.

#7   (1) Crossing altitudes at specific Distance Measuring Equipment (DME's), (2) Known traffic delays.

#8   Crossing altitude restrictions, holding clearances. <u>Any</u> clearance that ground, tower, departure, approach or ARTCC can give now over voice should be able to do visually.

UNWANTED SERIVCES.

OBSERVATIONS.   The number of services that should not be part of
Data Link   were   minimal;   examples   are   emergency   calls   and
traffic   information.   One   pilot wanted emergency   information
by both voice and Data Link.

.——.

Question 11.   What ATC services, if any, should not be part of
the Data Link system?

GAT Pilots

#1   Emergency calls unless they were a backup to voice.   Traffic
calls.   You don't want your head inside the A/C when there is
traffic close by.

B-727 Pilots

#1   None really.

#3   Course deviation for WX, traffic information.

#5   In an emergency, I would want it transmitted, both via Data
Link and verbal.

#6   Other traffic location(s)

#8   He   should   not   be able to remotely   control   any   airplane
through the Auto-pilot.

        If there are any other comments you would
        wish to express on the ATC portion of the
        Data Link system, use this page and the back.

GAT Pilots

#3   I   would like to see the message list function as a   scroll,
rather than excess information starting at top again.

#4   Possibly   to   let   you know if   you're   in   sequence   behind
another aircraft.

B-727 Pilots

#1   My   only   request   would be   positive   verification   between
flight and ATC regarding clearance acceptance.

#3   (1)   The use of Data Link would decrease the possibility   of
misunderstanding   messages between pilots and   controllers.

        (2)   For   routes   that   require position   reports   (as   over
ocean),   it would greatly decrease pilot and   controller workload.

(3) It makes acquisition of WX information much easier than the present system.

#4 I would be the last one to lose the "party line." I like the chatter, the quips, ATC admonitions, and mainly "How goes it" ahead of us, especially during the descent and approach phase. Turbulence levels, good ride levels, windshear on final, good area of passage between thunderstorms, flights that missed on approach ahead of us--all those nice things I am UNABLE to lose thanks to Data Link. But that's probably inevitable and the way of progress.

#6 I believe the ATC portion of the Data Link should strive toward becoming a true two-way communicating system for exchange of as much system information as possible.

#8 Let's all work to get this in the system as soon as possible. I believe it is much safer than voice.

WEATHER SERVICES.

OBSERVATIONS. This question dealt with the four Weather Service formats. Eight factors are listed for each service. In general, all average ratings were FAIRLY GOOD or above. The standard deviation was fairly high, indicating a wider range of ratings. The "Return to MAIN" concept was rated lowest in most cases. Amount of information on surface observations and terminal forecasts was rated lower by GAT pilots. The B-727 pilots rated amount of information (Winds/Temp) low. Several comments were made by the pilots concerning general format, content, amount of information, and logic.

STATISTICAL RESULTS. All observed p values were at or below the 0.05 level of significance (except those noted in table H-6), thus, suggesting a preferred rating. This rating was predominately in "5" or "FAIRLY GOOD."

Question 12. Rate the format of each of the four weather services on the following factors. Use the standard scale in making responses and circle the appropriate number. Please comment on each service as needed on the bottom of the next page (use the back of this page if necessary).

Surface Observations

	GAT		B-727		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	5.5	1.0	5.88	0.99	5.75	0.9
Information retrieval time	4.75	1.89	5.13	1.46	5.0	1.54
Clutter	5.0	1.41	5.5	1.69	5.33	1.56
Information clarity	5.0	1.41	5.75	1.28	5.5	1.31
Amount of information	5.0	2.0	5.75	0.89	5.5	1.31
Ambiguity	6.0	0.82	5.5	1.2	5.67	1.07
Time or valid times concept	6.5	0.58	5.88	0.64	6.08	0.67
"Return to MAIN" concept	6.25	0.96	4.5	2.14	5.08	1.98

Terminal Forecast

	GAT		B-727		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	5.5	1.0	5.88	0.99	5.75	0.97
Information retrieval time	5.0	2.0	5.25	1.67	5.17	1.7
Clutter	5.25	1.5	5.5	1.41	5.42	1.38
Information clarity	5.5	1.73	5.75	1.04	5.67	1.23
Amount of information	4.75	2.06	5.5	0.93	5.25	1.36
Ambiguity	6.25	0.96	5.38	1.3	5.67	1.23
Time or valid times concept	6.25	0.5	5.88	0.64	6.0	0.60
"Return to MAIN" concept	6.25	0.96	4.5	2.14	5.08	1.98

PIREP

	GAT		B-727*		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	6.25	0.96	6.5	0.58	6.38	0.74
Information retrieval time	5.25	2.22	5.5	2.38	5.38	2.13
Clutter	5.5	1.73	6.5	0.58	6.0	1.31
Information clarity	5.5	1.73	6.5	0.58	6.0	1.31
Amount of information	5.25	0.96	5.75	1.26	5.5	1.07
Ambiguity	6.25	0.96	5.75	1.26	6.0	1.07
Time or valid times concept	6.75	0.5	6.0	0.82	6.38	0.74
"Return to MAIN" concept	6.25	0.96	5.25	1.71	5.75	1.39

*Based on four responses (two crews did not view PIREP due to technical problem).

Wind/Temp Aloft

	GAT		B-727[*]		Overall	
	Avg	Std	Avg	Std	Avg	Std
Appearance	6.5	1.0	6.0	1.10	6.2	1.03
Information retrieval time	5.75	2.5	5.33	1.86	5.5	2.01
Clutter	6.0	2.0	6.0	1.10	6.0	1.41
Info clarity (DIR-VEL-TEMP)	6.25	1.5	5.0	2.0	5.5	1.84
Amount of info (3 Altitudes)	6.5	1.0	4.67	1.63	5.4	1.65
Ambiguity	6.5	1.0	5.67	1.37	6.0	1.25
Time or valid times concept	6.75	0.5	5.83	0.75	6.2	0.79
"Return to MAIN" concept	6.5	1.0	4.67	1.63	5.67	1.5

[*]Based on six responses.

Comments:
Surface Observations

GAT Pilots

#1   I believe some jets figure their T/O data on Press Alt or Density Alt.

#2   Dividing sky line so that visibility has a line of its own would make information a little easier/faster to interpret.

B-727 Pilots

#1   Standard WX Bureau information.

#4   For destination, I would like to see more information --probably same as on latest.

#5   Good.

#6   Format of the WX report is a bit different from that which I am used to seeing.

#7   When requesting weather, after pressing desired station, why hit "Send"? Seems like an extra step.

#8   Again, why use the lower portion to signal pilots?   Pilot parenthesis the "Return to MAIN" Concept and writes "Pilot Option." Use similar format that we see from National Weather Services. Made up acronyms; I HATE them.

Terminal Forecast

GAT Pilots

#1   The addition of forecast winds, outside air temp, and min altimeter would be nice.

#4   Should also include projected visibilities.

B-727 Pilots

#1   Standard WX Bureau information.

#4   OVC 5 miles is not enough information. Need to know ceiling.

#5   Good.

#6   Too much information and not in exactly the format I am used to seeing in the various formats I see in weather offices. You could allow the forecast for all the time periods that are "post" (ago) to drop off the screen so that all that would be showing would be present and future.

#7   Same as before.

#8   Same comments as before.

PIREP

GAT Pilots

#1   A comments section that might include turbulence, icing, cloud layers, etc., would be helpful.

#2   If more than one PIREP, how are others displayed? Are they queried, or is only the most recent displayed?

B-727 Pilots

#1   UNABLE to answer PIREP. We received no PIREPS on any Data Link run.

#2   Got none.

#4   Good useful information such as icing levels, turbulence, thunderstorm activity

#5   Good.

#7   Same as before.

Wind/Temp Aloft

GAT Pilots

#1   Good.

#2   Very clear, easy to interpret display. All reports   should
have the option of returning to the request stage rather than all
the way back to Main Menu.

#3   (General Comment for all WX Products)   All of them take   too
long.   Also, don't need touch for WX.   Just display   the
information following an audible alarm.

#4   (FD's) Good.

B-727 Pilots

#1   Would like altitudes for every 2,000 ft from 18,000-41,000.

#2   Here is an opportunity to add comments based on   computer
modeling.   For example, if there is a large wind direction or
velocity change between altitudes, a note or warning could be
given for a specific area.   The note could be, e.g., expect 50%
possibility CAT between FL 250 and FL 280 within 50 nmi of (Fix)
or (Coordinate), expected intensity--light.

#3   (Remarks   apply   to all)   The   presentation   requires
considerable effort to read when lengthy messages are presented.
The letters/numbers produce a sort of halo that is difficult to
see through. Short messages are no problem. The   retrieval time
for requested messages is too long and one is not always sure the
request is being processed.

#4   Good information, but would like to be able to request other
levels as needed.   (Need to look at other levels than the three
presented.)

#5   Need more altitudes.   Three is. good, but more would be
better.

#6   I would like the ability to request Wind/Temp aloft "AT   F/L
330 Only" (for example).

#7   Same as before. Why show last station queried on MAIN
menu?   It tells us nothing useful.

#8   (Use real words, no acronyms or made up abbreviations.)
This applies to all formats.

LOCID MENU DESIGN.

OBSERVATIONS. The LOCID menu factors were, in general, rated higher by GAT pilots than B-727 pilots. The menu of LOCID codes was rated FAIR by both groups. The comments centered on actual implementation, number of LOCID's, ambiguity of LOCID codes, etc. The LOCID menu concept and time to input factors were rated lower by B-727 pilots.

STATISTICAL RESULTS. The factor "Menu of LOCIDS concept" had an observed p value greater than 0.20. This indicates a variety of ratings from the pilots. Similarly, the "Time Required..." and "LOCID menu..." faster had observed p value between 0.10 and 0.15. All other factors had p values at or below 0.05 indicating a preferred response.

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Question 13. The weather services required you to select a location identifier (LOCID) (e.g., LAX or SAT) from the LOCID menu, depress enter and wait in the LOCID menu while the service info was gathered. The LOCID menu displayed the location code you had entered. Rate the design concepts on the following factors. Use the standard scale in making responses and circle the appropriate number. Please comment in the area provided (use the back of this page if necessary).

	GAT		B-727		Overall	
	Avg	Std	Avg	Std	Avg	Std
Menu of LOCID's concept	5.0	1.41	4.5	1.85	4.67	1.67
Time required to input/enter	5.5	1.0	4.86	1.35	5.09	1.22
Possibility for error	5.75	0.96	5.57	1.27	5.64	1.12
Number of "keystrokes"	5.0	0.82	5.71	0.95	5.45	0.93
LOCID menu of location codes	4.75	1.89	4.5	0.55	4.6	1.17
LOCID remaining on format (to request another service at the same location)	6.0	1.0	5.0	1.22	5.38	1.19

Comments:

GAT Pilots

#1 Concept is OK, but how will it be programmed? The time to enter is no problem. Possibility for error is low, at least with my fingers. Number of keystrokes might be reduced by changing "Send" to "Correction."

#2 This is an area where both concepts could be used. A menu of LOCID's for the local area and the keyboard for distant places.

#3   Could not possibly list all potential LOCID's. Some means is necessary for pilot to enter LOCID's.

#4   There's always a possibility for error using the touch type pad.   Turbulence could make it very difficult to select the . correct pad the first time.

B-727 Pilots

#1   This system is really pretty good. Maybe the display could be cleaned up just a bit, but overall it's acceptable.   I don't think many errors would come from this; besides, they're easy to catch should they occur.

#2   Since there is no airport menu, it is possible not to know an identifier or to enter the wrong identifier (when not in the on-screen menu).   This could lead to getting weather for one location which you believe to be from another.

#3   The LOCID's concept is good.   However,   there should be capability to type in or request stations that may not be listed. Time required to obtain information seems excessive.   The number of keystrokes could be reduced.

#4   Not bad system and fairly easy to use, but I believe that a quick/slow scroll through all identifiers in a data base would be less prone to error (such system exists in NAV STAR-1, LORAN-C).

#5   The only problem with this format is, let's say you have an emergency and have to divert to some place not on the LOCID's menu.   It would be nice to put in what station we want weather for.

#6   Once I have selected the location from the LOCID menu, the request should be sent rather than having me then press the sent . button.

#7   Seems like the keyboard concept would add versatility   to ' system without cluttering screen.

#8   I should be able to type in information as to what I want.

LOGIC OPTIONS.

OBSERVATIONS.   The   "SENT"   message after touching SEND was considered   a   very   desirable   option.   The confirmation it provides that the system is working is critical. The length of time "SENT" appears was too short. Using the word "WAITING"

in addition to "SENT" was suggested. The requirement to touch "SEND" was considered an unnecessary extra step by one pilot.

Question 14. After selecting a location identifier and touching "SEND," a message flashed near the bottom of the screen "SENT." Is this a desirable option? Please comment.

	GAT	B-727
Yes	1,2,3,4	1,2,3,4,5,7,8
No		6
Maybe		

Comments:

GAT Pilots

#1 However, it stayed on the screen for too short of a time. Consequently, I went back to the MAIN menu to look for the question mark.

#2 Since the system waits for the information to be returned, a "SENT," and possibly a "WAITING" message are helpful.

#4 Again, there has to be some way the pilot knows his request has been sent.

B-727 Pilots

#1 At least you know the system is attempting to retrieve your information.

#2 Necessary confirmation.

#3 To assure message went out.

#4 Definitely.

#6 It's an extra step that should be eliminated.

#7 Do not need "SEND" button. Pushing Station ID should send it AUTO. "SENT" should remain on screen.

#8 Very much.

The logic in which weather information remains on screen until pilot input was considered very desirable. The ability to read the message more than once and/or copy it onto paper is necessary.

Question   15. Aftex the weather information is displayed, the message remained until you touched main. Is this a desirable option? Please comment.

	GAT	B-727
Yes	1,2,3,4	1,2,3,4,5,6,7,8
No		
Maybe		

Comments:

GAT Pilots

#2   Option should be added to go back and request some information (product) from another location.

#3   Pilot may want to refer to it between other chores.

B-727 Pilots

#1   Please see comments in question 1, Overall Concepts.

#3   Any message should remain until the pilot has understood and released it.

#4   Want to see it and copy it.

#6   WX has to be read more than once to assimilate.

TIME REQUIREMENTS.

OBSERVATIONS. For all weather services, the time diverted from the flying task was considered acceptable by most. Cne B-727 pilot indicated both minimal and acceptable. One B-727 pilot felt all services required excessive time because of historic data that provides no information.

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Question   16. The Data Link system as implemented will require one to divert time/attention from the flying task. For each service, state whether the time required was: minimal, acceptable, or excessive or depends on ...?   Circle the appropriate response for each service. Please comment on those services requiring excessive time ana/or, if necessary, discuss the depends on ...

Surface Observation	Minimal	Acceptable	Excessive	Depends
GAT		1,2,3,4		
B-727	5,8	1,2,3,4,7,8	6	

Terminal Forecast	Minimal	Acceptable	Excessive	Depends
GAT		1,2,3,4		
B-727	5,8	1,2,3,4,7,8	6	

Pilot reports	Minimal	Acceptable	Excessive	Depends
GAT		1,2,3,4		
B-727	5,8	1,2,4,7,8	3,6	

Winds/Temp aloft	Minimal	Acceptable	Excessive	Depends
GAT	2	1,3,4		
B-727	5,8	1,3,4,7,8	2,6	

*B-727 #8 Chose both minimal and acceptable for all services.

Comments:

GAT Pilots

#3   Although acceptable, an improved format and quicker response would greatly improve the service.

B-727 Pilots

#1   When one turns a frequency to request information and then listens and writes that information, time is diverted from the flying task. The Data Link method of information retrieval is superior to voice and pencil.

#2   See prior FD comments (i.e., what does this tell me?).

#3   The information is adequate again. The presentation or matrix produces a sort of halo that makes messages that fill the scope difficult to read.

#4   Time used was no more than it would take for a verbal communication.

#6   For SA's, trim the screen information to only applicable information, i.e., no historic reports, only current or last two or last hour.
    For FT's, forecasts for time periods past should be eliminated; format should resemble the format seen in WX office. Normal format.
    For FD's, screen should show only altitudes I request.

OVERALL WEATHER DESIGN

OBSERVATIONS.

The overall Weather Data Link design was rated FAIRLY GOOD. Problem areas listed were centered on the information presentation, e.g., letter size, amount, etc. The observed level of significance was less than 0.05 suggesting a preferred rating, i.e., "5," or "FAIRLY GOOD."

Question 17. Improper/incomplete system designs can result in pilot errors. Overall, how would you rate this Data Link system - Weather Services design. Use the standard scale provided. If you feel design problems exist, specify the areas you find unsatisfactory, i.e., where the potential for errors is most prevalent. Please provide your suggestions on how we might redesign the system to overcome these problems.

System Design - Weather Rating

GAT		B-727		Overall	
Avg	Std	Avg	Std	Avg	Std
5.38	0.95	5.0	0.85	5.14	0.71

Problem areas/suggestions:

GAT Pilots

#1   By changing the size of the letters. Emphasis can be made to the pertinent information. WX information for the most part is nonemergency in nature and can be requested in a relatively relaxed atmosphere.

#2   Automatically having the Data Link able to provide 6-9 LOCID's for the area the plane is flying through.

#3   Less clutter, screen more information; probably requiring sequential screens.

B-727 Pilots

#2   If visual presentations available through the National WX Service could be displayed, it would enhance the system greatly.

#3   Locate the device in the cockpit for the least effort for the pilot both for observation and operation. Reduce keystrokes to a minimum.

#4   Not enough information available in current system.

#5   Same as question 13.

#6   I think critical messages such as altitude should be acknowledged by both pilots before disappearing from screen. I think the program should be revised to include the appropriate words of "Climb" or "Descent," or else eliminate those words and include "Change to"...

SUGGESTED SERVICES.

OBSERVATIONS. The pilots made numerous suggestions on weather services to be part of future Data Link designs. A few suggestions were as follows: SIGMETs, radar summaries, windshear, hourly sequence reports, etc. One pilot wants to be able to show weather sequences of a single station to determine trends (if any).

Question 18. The design of a major system normally goes through numerous iterations. What weather services would you consider an absolute requirement in future designs and/or as part of operational systems?

Suggested services:

GAT Pilots

#1   See questions 10 and 12.

#2   Adding SIGMET's to the current four chores.

#3   Those currently used with more information: visibility, restrictions to vision, runway conditions, icing conditions, etc. Ground WX radar pictures in color.

#4   Possibly radar summaries for precipitation.

B-727 Pilots

#1   Hourly sequence reports.

#2   See above (question 17).

#3   Windshear info -- This should be sent out automatically.

#4   Need to be able to request information as needed.

#5   Same as question #13.

#6   (1) Latest hour (elapsed time) of WX reports, (2) WX at requested locations.

#7   Runway conditions.   Have ability to show several WX sequences of same station to pick up a trend.

#8   Any segment that effects any area near our flight path should automatically be sent to us.   Windshear, any unusual weather.

UNWANTED SERVICES.

OBSERVATIONS. The number of weather services that should not be part of Data Link were minimal.   One pilot would take all services.

Question   19. What weather services, if any, should not be part of the Data Link system?

GAT Pilots

#2   Area forecasts--too much information to try to put on little screen.

B-727 Pilots

#1   None; I'll take all I can get.

#3   No change necessary.

#4   Should be able to uplink all services as needed.

#6   (1) Alt setting in millibars.
      (2) Cloud covering in 1/10's of sky coverage.
      (3) Types of clouds, i.e., (as AC) other than CB.

          If there are any other comments you would
          wish to express on the Weather portion of
       the Data Link system, use this page and the back.

GAT Pilots

#4   Possibly using ground radar services for Data Link screens.

B-727 Pilots

#3   Condense messages as much as possible.

<u>OVERALL</u>.

<u>OBSERVATIONS</u>. The Main Menu was rated GOOD on all factors by GAT pilots. The overall appearance was rated GOOD by B-727 pilots; however, the other factors were only rated FAIRLY GOOD. GAT pilot comments were concerns with the Main Menu as the number of services available grows and the screen color. One B-727 pilot emphasized that Data Link should do anything that Voice can---"keep voice as a backup."

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Question 20. The Data Link display Main Menu provided for selection of WX services and message retrieval. Rate the Main Menu on the following factors. Use the standard scale in making responses and circle the appropriate number. Please comment.

	GAT		B-727[*]		Overall	
	<u>Avg</u>	<u>Std</u>	<u>Avg</u>	<u>Std</u>	<u>Avg</u>	<u>Std</u>
Overall appearance	6.0	0.0	6.14	0.69	6.09	0.54
Clutter	6.0	0.0	5.14	1.35	5.45	1.13
Time required to interpret	6.0	0.0	5.86	0.69	5.91	0.54
Amount of information	5.5	1.0	5.14	1.68	5.27	1.42

[*]Based on seven responses

Comments:

<u>GAT Pilots</u>

#1 Obviously (amount of information) will change with more services provided.

#2 Having Main Menu show location of last request of each type of information is a good idea. When different report is requested, most recent LOCID should automatically appear on the request screen, to be overridden by either a new LOCID or Keyboard.

#3 Would probably require sequential screens to provide additional information.

#4 Should break away from normal green format to a less distracting color.

<u>B-727 Pilots</u>

#3 Earlier comments regarding the display should be noted.

#4 Other than legibility of some numbers, display looked good.

#6   A   comment   on   this   critique -- All   Data Link   screen
representations   should   be   included in this critique to refresh
our memories since the display is new to us.

#7   No need to show ID of last station after WX information.

#8   A pilot should be able to pull up any WX   information,   ATC
requests,   100% of what we do with voice -- Keep voice as a
backup.

WORKLOAD.

OBSERVATIONS.   The   ATC workload ratings given   by GAT pilots
(acceptable)   were almost a full point higher than those given by
B-727 pilots   (low workload).   This may be due to the fact that
the GAT   pilot   was alone   whereas   the   B-727 portion utilized a
two   person   crew.   Ironically, however, the GAT pilots rated the
workload   lower   for the   weather services.   The   standard
deviation with B-727   pilots was   slightly higher.   The binomial
test was performed   on   this data   by   forming two categories (1,
2,   3 - LOW) and (4 and   5   - HIGH)   on the assumption that a
rating 1, 2, or 3   was   Acceptable, whereas a rating of 4 or 5
was Unacceptable.   For all ATC and   WX services   the p values
were all   less than 0.05,   except   terminal forecasts   and
PIREP's.   This   indicates that   for   all   services, except
terminal forecasts and PIREP's, a preferred rating   category was
chosen.   This category was the low (1-2-3) category.

Question   21.   For each of the services (and overall),   how   would
you rate   your   workload as it appeared during the flight.   Use
the scale below.   Indicate a rating for each and make comments
where applicable (e.g., ratings of 5 or 4).

    5 Completely saturated
    4 High workload
    3 Acceptable at all times, not too high OR low
    2 Low workload
    1 Very low, bored, need activity

Workload rating for:

	GAT[1]		B-727[2]		Overall	
	Avg	Std	Avg	Std	Avg	Std
Altitude assignment	3.33	0.58	2.43	0.53	2.7	0.67
Frequency Change	3.33	0.58	2.43	0.53	2.7	0.67
Surface observations	2.0	1.0	2.86	3.14	2.6	0.84
Terminal forecast	2.0	0.0	3.14	1.07	2.8	1.03
Pilot report	2.33	0.58	3.0	0.89	2.78	0.83
Winds/temperature aloft	2.0	0.0	2.86	0.69	2.6	0.70
Overall	3.0	0.0	2.75	0.71	2.82	0.60

[1]Based on three responses   [2]Based on seven responses

Comments:

GAT Pilots

#2   First frequency change comes just a level off, VOR passage, trying to get plane settled down for main part of flight, prefer Data Link at this point so I can respond when able.   Other frequency changes at low workloads, welcomed the change.

B-727 Pilots

#1   On UA..."Not Observed."

#2   As pilot flying, when the flying workload was high, the Data Link functions increased the workload further.   When workload was normal, interface with Data Link was good (Normal and acceptable).

#3   For the services normally required, workload rates of 3.

LOGIC DESIGN - OVERALL.

OBSERVATIONS.   The LOCID menu layout was rated FAIRLY GOOD by GAT pilots and FAIR by B-727 pilots.   The GAT pilots comments were centered on real world implementation.   The B-727 pilots requested more LOCID's and a keyboard. The observed level of significance was between 0.05 and 0.10, which indicates variety of pilot rating.

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Question 22. After initiating a weather service request, a LOCID menu appeared for you to input the location of interest.   Rate the menu layout using the standard scale provided.   Please comment and provide suggestions for improvement.

GAT		B-727		Overall	
Avg	Std	Avg	Std	Avg	Std
5.75	0.5	4.5	0.76	4.92	0.90

Comments:

GAT Pilots

#1   Good.   I'm curious as to how the LOCID's presented will be selected; i.e., will the operator program six LOCID's? Will the system provide LOCID's close to your route of flight?

#2   If software would permit, LOCID's that do not have current data, or none available, should be either flagged or eliminated from display.

#3   Worked well in this exercise, but impractical in real world. Need means for pilot to input LOCID's.

#4   I think individual keyboard input for identifier would be easier.

B-727 Pilots

#1   Given the display as it is, this method of station selection probably can't be improved upon too much.

#3   Efforts should be made to make available more stations.

#4   Will comment elsewhere on LOCID.

#5   Same as question 13.

#6   A little cluttered.

#7   Use keyboard to enter ID. Don't need additional step of hitting "Send" button. Leave word "SENT" on screen.

LOGIC OPTIONS.

OBSERVATIONS.   The logic flow associated with the LOCID menu/weather retrieval was acceptable by all. One pilot did not want to have to touch to retrieve the weather when available. One pilot commented that since the "SENT" message was so brief, he went to the MAIN menu to determine if the MAIN menu indicator was present.

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Question   23. After entering a weather request, the system remained in the LOCID menu (access to the Main Menu is possible by touching "Main" at lower left). Upon delivery of the requested service to the Data Link system, a message appeared at the bottom of the display indicating its availability. Upon touching the area, the weather information was presented. Was this logic flow acceptable?

	GAT	B-727
Yes	1,2,4	1,2,3,4,5,6,7,8,
No		
Maybe	3	

Comments:

GAT Pilots

#1   Once again, I did not see the "SENT" message and, consequently, went to the MAIN menu to look for the "?."

#2   Acceptable; not as necessary as the ATC MSG prompt.

#3   Do not need touch activity, just display information with
audible announcement.

<u>B-727 Pilots</u>

#1   Whatever is there will stay there until the user wants it.
A good feature.

#2   Rather than (?)--if available, so state.   If you don't,
pilot doesn't know if it is a malfunction or unavailable.

#3   (didn't answer, but said...).   For weather information,
I would prefer to have two keystrokes: (1) Select LOCID and (2)
Select Service.

#4   It follows the other ?   (MAIN menu) -- No time was lost.

The ability to make multiple weather service requests while
waiting for message delivery was considered a necessary option.
One pilot did state that "Data Link should answer one request at
a time...."   The words "desirable,"   "definitely," and "time
efficient" were used in the comments.

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Question   24. After making a weather request and while waiting
for the information to appear, you had the ability to make
another weather request (or view message lists). This capability
was not exercised.   Do you think that this is a necessary option
in the Data Link system?

	GAT	B-727
Yes	1,2,3	1,2,3,4,5,6,7,8
No	4	
Maybe		

Comments:

<u>GAT Pilots</u>

#2   This was not available for today's simulation.   On Winds
Aloft and Terminal Forecasts, pilot may want to view several
stations.

#3   This attempt crashed system during my exercise.

#4   I think the Data Link should answer one request at a
time; however, request of several different locations during one
flight is essential.

B-727 Pilots

#1   The whole idea should be to get as little or as much information quickly or as leisurely as one wishes commensurate with his existing workload.

#2   Desirable. More time efficient.

#4   Definitely, but not necessarily through the use of the keyboard device.

VISUAL ANNUNCIATION.

OBSERVATIONS. The annunciation (with "Touch for ATC Message") logic was acceptable. Emergency messages should be made by voice. Automatic delivery of ATC messages was not a desired feature. Pilot action to retrieve the information is required. Different tones or number of tones was suggested to discriminate weather and ATC messages. The test statistic/p value indicates a preferred choice, i.e., YES, in parts A and B.

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Question 25A. An incoming ATC message was annunciated by "Touch For ATC Message" at the bottom of the screen. Is this operation logic acceptable in all situations?

	GAT	B-727
Yes	1,2,3,4	1,2,3,4,5,6,7,8
No		

Comments:

GAT Pilots

#1   (Emergency/urgent) messages need to be sent by voice.

B-727 Pilots

#1   Urgent ATC messages should be accomplished by voice.

Question 25B. Or, for example, in a non-busy situation, such as when in the MAIN menu and no weather messages pending: Should the ATC message automatically appear without being required to touch the screen? Comment on other situations of interest.

	GAT	B-727
Yes		4
No	3,4	1,2,3,5,6,7,8

Comments:

GAT Pilots

#1   That would be a nice feature.

#2   Having the pilot touch the screen for ATC MSG is good. Alerts pilot that something important may be coming in. There should be different tones or number of tones for ATC vs WX messages.

#4   Some method must be used to let ATC know that the message was received.

B-727 Pilots

#1   See previous comment.

#2   Also--suggest flashing the annunciator so that message will not be overlooked. Stop flashing when acted upon.

#3   ATC messages should be positively acknowledged.

#4   I believe my comment elsewhere was, "I'll accept the messages when ready."

#6   The screen could "default" to the latest ALT heading, freq, route, etc.

#8   Pilot action should be required.

The Chi-square test resulted in significance levels as follows for the difference between Yes and No answers on questions 25A and 25B.

25A   Chi-square = 12.0 $p < .01$
25B   Chi-square = 4.45 $p < .05$

MESSAGE LIST-LOGIC OPTIONS.

OBSERVATIONS. The ability to retrieve a list of messages was a desirable option. One pilot would prefer a printer in addition to the display. The order of messages was a problem area for the tested system. Old information (frequencies, altitudes) are not necessary; present only the most recent message for each service. The test statistic/p value confirms that a preferred response was made, i.e., YES.

Question 26. Do you think the ability to retrieve a list of messages received (from the MAIN menu) is a desirable option on the Data Link system?

	GAT	B-727
Yes	1,2,3,4	1,2,4,5,6,7,8
No		3

Comments:

GAT Pilots

#2 Most recent message should be on top of screen, scrolling off bottom. Not the page wrap that is currently programmed.

#3 Very.

#4 However, again I think buttons should be used instead of touch pad.

B-727 Pilots

#2 Problem, after eight messages you can start losing them due to overflow.

#3 A better method would be to have messages come out on a printer along with the usual presentation.

#4 Definitely--Important--Do not delete.

#6 However, you can rid it of previous frequencies when there have been two changes, i.e., the frequency I was on three frequencies' ago is useless to me and just is clutter, so dropping the second historic frequency in order to the clear the screen up would be helpful.

#7 They must be in chronological order. Recommend most recent on bottom. No need to retain more than last frequency assigned and last altitude assigned.

The Chi-square test showed a significance level as follows for the difference between Yes and No answers in question 26.

Chi-Square = 8.33   p < .01

SCENARIO SUTIABILITY.

OBSERVATIONS. The scenarios were appropriate for evaluating Data Link. Most would have preferred longer runs and/or additional runs. One pilot said, "Work me harder next time." The test statistic/p value confirms that the YES was a preferred rating.

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Question 27. Do you think the scenario you flew in for this test was appropriate for evaluating Data Link? Please comment.

	GAT	B-727
Yes	1,2,3,4	1,3,4,5,6,7,8
No		2

Comments:

GAT Pilots

#1   Flying both scenarios twice, one in voice and one in Data Link, would have been nice.

#2   Although route was relatively short, after initial climb and level off, most IFR flights are low in workload, exception being turbulence, or possible East Coast plan.

#3   Sort of. A longer trip, utilizing more realistic terminal operations probably would be more revealing.

#4   Especially liked weather reports on ground.

B-727 Pilots

#1   Runs could have been a little longer.

#2   I think longer legs would be advisable to give the pilot flying longer to interface with the Data Link.

#3   It was adequate for this phase of development.

#4   It was busy enough to exercise the crew and Data Link.

#8   Work me harder next time.

The Chi-square test showed a significance level as follows for the difference between Yes and No answers in question 27.

Chi-square = 8.33   p < .01

DISPLAY LOCATION.

OBSERVATIONS. The cockpit location of the Data Link display was acceptable. The B-727 pilots emphasized the lack of "real estate" in the 727; the weather radar position for Data Link was acceptable, but the weather radar is needed as well. The test statistical p value confirms that the YES was a preferred rating.

Question   28. Was the cockpit location of the display acceptable given the type/importance of the information?

	GAT	B-727
Yes	1,2,3,4	2,3,4,5,6,7,8
No		1

Comments:

GAT Pilots

#1   Combining into an EFIS/DFIS would be even better; but with conventional instruments it was fine.

#2   Location was easily visible from either seat, out of path of normal scan, but near enough for a flashing message to be caught by eye

B-727 Pilots

#1   A 727 cockpit is a difficult place to locate this device. Maybe dual heads closer to users.

#2   Better--Yoke mounted dual displays to give better "head up" capability

#3   For a multiple crew operation, the location was adequate. For a single pilot operation, the location should be more accessible.

#4   But in the future it should be on a CRT elsewhere. I need the WX radar more.

#8   But where do we put the radar?

The Chi-square test showed a significance level as follows for the difference between Yes and No answers in question 28.

Chi-square = 8.33 p < .01

INPUT TECHNOLOGY.

OBSERVATIONS. The touch-sensitive input technology for airborne use was acceptable to most. Concerns were expressed about use in turbulence. Two pilots found the technology unacceptable and suggested buttons or a mouse. One pilot called the technology "a must."

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Question 29. What do you think of the touch sensitive input technology as a concept for airborne use? Please comment.

	GAT	B-727
Acceptable	1,2,3	1,2,5,6,7,8
No preference		3
Unacceptable	4	4

Comments:

GAT Pilots

#2   May be difficult for people with FAT fingers, or in turbulence. Did not always pick up on first or second time.

#4   Buttons or something else. Even in this scenario wrong pads were touched by other fingers and, if accidentally touched twice, the screen changed each time.

B-727 Pilots

#3   The system is open to some error. At times the requests did not take. In turbulence, it could be difficult. It's not as positive as a button.

#4   I would rather see a mouse and enter button.

#6   A must.

#7   This system worked fine.

PRE-TEST TRAINING.

OBSERVATIONS. Most everyone was satisfied with the briefing and training received on Data Link. One pilot would have preferred more information to study. The test statistic/p value confirms the Yes response preference.

Question 30. Were you satisfied with the briefing/training you received on the Data Link system? Please comment.

	GAT	B-727
Yes	1,2,4	1,2,3,4,5,6,7,8
No	3	

Comments:

GAT Pilots

#1   Good job.

#2   Understood system and ease of use. Most is straightforward logic. Very acceptable.

#3   Would have preferred more information to study.

B-727 Pilots

#3   The briefing was thorough and made the test easy and effective.

#4   Very good and efficient.

The Chi-square test showed a significance level as follows for the difference between Yes and No answers in question 30.

Chi-square = 8.33 $p < .01$